# SPIROS PATSOURAKOS
# CURRICULUM VITAE

# Contents

## 0.1 Contact


Dr Spiros Patsourakos — Associate Professor
Office Φ3-406 — *tel:* +(30) 26510 08478
University of Ioannina — *Fax:* +(30) 26510 08699
Department of Physics - Section of Astrogeophysics — *e-mail:* spatsour@cc.uoi.gr
451 10 Ioannina
Greece


## 0.2 Studies

- **B.Sc. in Physics**, 1995, Aristotle University of Thessaloniki, Greece. Diploma Thesis:"Evaluation of a White-Light Coronagraph on-board the Solar Probe Mission". Supervisors: Dr. Jean-Claude Vial, Prof. Loukas Vlachos.
- **M.Sc. in Plasma Physics**, 1997, University PARIS XI, Orsay, France. M.Sc. thesis on "Diagnostics of the lower transition region in coronal holes and the quiet Sun". Supervisors: Dr Jean-Claude Vial, Prof. Karine Bocchialini.
- **Ph.D. in Plasma Physics**, 2000, University PARIS XI, Orsay, France. Thesis topic:"Investigation of Coronal Heating and Solar Wind Acceleration in Coronal Holes". Supervisor Dr Jean-Claude Vial. Ph.D. Committee Drs A-H Gabriel, S. Koutchmy and Profs. R.M. Bonnet, S. R. Habbal, J. Heyvaerts.

## 0.3 Professional Activity

- 1995-1996: Undergraduate student in the Institut d Astrophysique Spatiale of the PARIS XI University under the frame of the ERASMUS programme.
- 1997-2000: Ph.D. dissertation at Institut dB'AAstrophysique Spatiale in University PARIS XI at Orsay.
- 1997-2000: Scientific planner of the CDS and SUMER instruments on-board the SOHO satellite during several intervals from the Multi-Experiment Data and Operations Center for SOHO (MEDOC) at Orsay.
- February 1998: Participation in an observing campaign of the 1998 total solar eclipse in Guadeloupe, France.
- September 1998-December 1998: Scientific visitor at Institut dB'AAstrophysiqua de lB'AEspacio (IAFE) of the Buenos Aires University.
- 2000-2001: Research assistant at the Mullard Space Science Laboratory of University College of London in UK. Support member of the UK Solar Physics Research Facility (SURF).
- June 2001: Visitor at the Goddard Space Flight Center of NASA for the scientific operations of the CDS instrument of the SOHO satellite.
- December 2001 - July 2005: Assistant Research Professor, George Mason University, Vienna, VA.
- 2005-2006 Military service in the Hellenic Air Force.

- June 2006 - July 2009: Assistant Research Professor, George Mason University, Vienna, VA, USA.
- July 2009-2015: Assistant Professor, University of Ioannina, Department of Physics
- July 2010- August 2010: Scientific visitor at Goddard Space Science Center, Greenbelt, USA and Naval Research Lab, Washington DC, USA.
- August 2011: Scientific visitor at Royal Observatory of Belgium, Brussels, Belgium.
- August 2012: Scientific visitor at Naval Research Lab, Washington DC, USA.
- 2015-: Associate Professor, University of Ioannina, Department of Physics

## 0.4 Teaching

- 2009- Solar Physics, Department of Physics, University of Ioannina, http://ecourse.uoi.gr/.
- 2009- Space Weather, Department of Physics, University of Ioannina, http://ecourse.uoi.gr/.
- 2010-2012 Experimental Physics II, Department of Chemistry, University of Ioannina
- 2012 Observational Astrophysics, Department of Physics, University of Ioannina
- 2012-2013 Introductory Physics, Department of Chemistry, University of Ioannina
- 2014- General Physics, Department of Physics Postgraduate Programme in Meteorology, University of Ioannina
- 2014- Linear Algebra and Analytical Geometry, Department of Physics, University of Ioannina, http://ecourse.uoi.gr/ .

## 0.5 Teaching in Schools

- "Initial Stages of Coronal Mass Ejections", First School of the Hellenic National Space Weather Network, Portaria, 25-27 February 2013
- "Coronal Mass Ejections", First summer school of the Hellenic Astronomical Society. Athens, 1-5 September 2014

## 0.6 Supervision of Undergraduate Diploma Thesis

- 2009-2010 Coronal Heating, Minas Mplazoudakis, Department of Physics, University of Ioannina
- 2012-2013 Parametric study of wave disturbances in the low corona, Evi Xristonasi, Department of Physics, University of Ioannina
- 2013- Study of Flux Ropes before and during Coronal Mass Ejections onsets with SDO Observations, Christos Tagikas, Department of Physics, University of Ioannina
- 2014-2015 Study of the solar sources of major geomagnetic storms during cycle 24, Georgia Petroulea, Department of Physics, University of Ioannina
- 2014- Statistical study of geomagnetic storms during cycle 24, Chara Karipidou, Department of Physics, University of Ioannina

## 0.7 Participation in M.Sc. Committees

- Eleni Nikou, Department of Physics, University of Ioannina, 2015
- Xristina Magou, Department of Physics, University of Athens, 2015
- Euaggelia Liokati, Department of Physics, University of Ioannina, 2015

## 0.8 Participation in PhD Committees

- Chloe Guennou, Uviversity Paris XI, 2013, rapporteur
- Eleutheria Mitsakou, University of Athens, 2014, examiner
- Vincent Joulin, University Paris XI, 2015, rapporteur
- Athanasios Kouloumvakos, Department of Physics, University of Ioannina, member of the advisory committee

## 0.9 Supervision of Post-doctoral Research Associates

- Veronica Ontiveros, 2010-2012, Study of Coronal Mass Ejection Related IP Shocks
- Olena Podladchikova, 2013-2014, Study of Forces Acting on Coronal Mass Ejections during their IP propagation,

## 0.10 Textbooks in preparation

- Solar and Space Physics, C. Alissandrakis, A. Nindos, **S. Patsourakos**, 2015
- Observational Astrophysics, C. Alissandrakis, A. Nindos, **S. Patsourakos**, 2015

## 0.11 Research Interests

- Solar and Heliospheric Physics
- Space Weather
- EUV, SXR and optical spectroscopic and imaging observations of the lower solar atmosphere and of the inner and outer corona
- Coronal and transition region heating and structuring
- Solar wind sources in the low corona
- Coronal jets and mini-CMEs
- EUV waves
- Prominences
- Coronal Mass Ejections: Initiation and Propagation into the IP medium
- Assessment studies for new instruments
- Solar cycle

## 0.12 Publications in Refereed Journals and Special Volumes

**R1** *Solar Chromospheric Structures Observed in UV Resonance Lines: A Multivariate Analysis Approach*, **S. Patsourakos**, K. Bocchialini J. C. Vial, 1999, C. R. Acad. Sci., 326, 337

The authors present the results of a statistical analysis carried out from a data base of six solar chromospheric emission lines recorded simultaneously and with high spectral resolution. An empirical and a clustering method for separating the different solar structure contributions have been used and found to be in good agreement. Mean profiles corresponding to the different populations have been built. Correlations of different parameters for each profile allowed one to deduce different properties of the solar chromosphere, such as the existence of magnetic canopies and downflows in active regions.

**R2** Outflow Velocities at the Base of a Polar Coronal Hole during the Total Eclipse, S. Patsourakos, J-C Vial, J-R Gabryl, S. Koutchmy U. Schuhle, 1999 Space Science Reviews, 87,291

Polar coronal holes represent the most convincing site from which the high-speed solar wind originates. Here we report high-accuracy Doppler shifts measured in the O VI (1037.6 Å) line obtained by SUMER on SOHO inside an interplume region within the south polar coronal hole. We infer limits on the outflow velocity and draw hints about the flow geometry.

**R3** *Transition-Region Network Boundaries in the Quiet Sun: Width Variation with Temperature as Observed with CDS on SOHO*, **S. Patsourakos**, J-C Vial, A-H Gabriel, N. Bellamine, 1999, Astrophysical Journal, 522, 540

We report here the results of a study of the temperature variation of the network boundary thickness in the quiet-Sun transition region. A Fourier-based two-dimensional autocorrelation method has been applied to $240''$x$240''$ rasters obtained in several transition-region lines by the CDS spectrometer on SOHO. The quantitative variation of the network boundary width with temperature has been obtained for the first time in a full two-dimensional field. It appears that network boundaries have an almost constant width up to a temperature of about $10^{5.4}$ K and then fan out rapidly at coronal temperatures. This expansion of the transition-region network boundaries with temperature is found to be quantitatively in agreement with earlier theoretical models of the transition region.

**R4** *Outflow velocity of interplume regions at the base of Polar Coronal Holes*, **S. Patsourakos**, J-C Vial, 2000, Astronomy & Astrophysics, 359, 1

We report on SUMER/SOHO observations at 1.05 Rsun of a well identified interplume region in a South Pole Coronal Hole. Combination of Doppler shifts and Doppler dimming measurements allowed to determine, for the first time, the total wind outflow velocity ( 67 km/s) at this height. Our calculations of the outflow velocity benefit from co-spatial and almost co-temporal observations. This large outflow velocity is a strong argument in favour of the interplumes being the main source of the fast solar wind. We find that the mass flux density through the observed interplume is 4.8 $10^{-10}$g cm$^{-2}$ s$^{-1}$ which yields $10^{-15}$g cm$^{-2}$s$^{-1}$ at 1 AU with an expansion factor of 11.

**R5** *Analysis of a UV event in a Polar Coronal Hole*, 2001, S. Patsourakos, J-C Vial, 2000, Solar Physics, 203,39

We present observations of a UV event which occurred in a polar coronal hole. They were

obtained by SUMER on SOHO in several chromospheric and transition region spectral lines. Its birth site was about 50 arc sec inside the limb and in a network lane showing a net outflow before its initiation. The event had an extension of about 5 arc sec along the slit, a duration of about 3 min and was characterized by a large increase of intensity together with a significant line broadening with, however, downflows of about 50 km/s being dominant. Proper motions with a velocity of about 10 km/s were also observed. The event appeared at middle transition (O VI) temperatures and it simultaneously showed up in chromospheric (OI, Ly G'A) and low transition region (C II) temperatures. We discuss this event in view of different scenarios to account for it. Our event could be a part of the large family of quiet-Sun explosive events observed by Ryutova and Tarbell (2000) taking place in polar coronal holes that are triggered by magnetic reconnection in the low solar atmosphere.

**R6** *Solar cycle variation of the temperature structure with the core of coronal streamers*, C. R. Foley, **S. Patsourakos**, J. L. Culhane, D. MacKay, 2002, Astronomy & Astrophysics, 381, 1049

We use the Coronal Diagnostic Spectrometer onboard the Solar and Heliospheric Observatory (SOHO) to analyze conditions in coronal streamer structures observed close to solar minimum (1996 July 8) and near maximum (1999 August 5). We measured the intensities of emission lines from Fe IX-XV ions and found the most intense emission to be from Fe XI at solar minimum and from Fe XV at solar maximum. We then used the line ratio method with transitions in selected ions to extract the radial temperature behavior in the structures. The solar minimum peak values were about 1.4 MK at 1.3 Rsun, while values derived close to solar maximum were consistent with the Yohkoh observations at the last maximum, displaying an apparently asymptotic temperature of around 2.2 MK above 1.2 Rsun. We discuss the observations in relation to possible mechanisms for energy deposition in large coronal structures at different phases of the solar cycle.

**R7** *Intermittent behavior in the transition region and the low corona of the quiet Sun*, **S. Patsourakos**, J-C Vial, 2002, Astronomy Astrophysics, 385, 1073

We present an analysis of light-curves obtained in the O IV and Ne VIII transition region and low corona lines, that were simultaneously recorded in a quiet Sun region by SUMER/SOHO. By using the flatness spectrum of the observed light-curves we searched for intermittency signatures. It was found that a significant proportion of points in the observed area exhibit clear indications of intermittency, irrespectively of their intrinsic intensity. Our findings give favor to an impulsively heated transition region and corona via intermittent-type MHD turbulence.

**R8** *SOHO Contribution to Prominence Science*, **S. Patsourakos**, J-C Vial, 2002, Solar Physics, 208, 253

We present the main current issues concerning prominence studies. We recall the large range of plasma parameters found in prominences which makes the work of the MHD modeler more difficult. We also summarize the capabilities of the SOHO instrumentation. We present and discuss the most recent SOHO results concerning the determination of temperature, densities, and velocities. We put some emphasis on the different morphologies observed, the diagnostic capabilities of the Lyman lines profiles when accompanied by improved non-LTE modeling, and the information gathered from the first prominence oscillations measured from space. We also make an account of eruptive prominences. We finally discuss what could be done with present and future SOHO data to improve our

understanding of prominences.

**R9** *Ion Effective Temperatures in Polar Coronal Holes: Observations verus Ion-Cyclotron Resonance*, **S. Patsourakos**, S. R. Habbal, Y.Q. Hu, 2002, Astrophysical Journal, 581, 125

The resonant cyclotron interaction between ion-cyclotron waves and solar wind species is considered nowadays to be a strong candidate for heating and acceleration of protons, $\alpha$-particles, and heavy ions. A crucial physical parameter for determining the amount and the location of significant heating and acceleration, which the different solar wind ions receive from the waves in the frame of the ion-cyclotron mechanism, is their charge-to-mass ratio q/m. Therefore, comparisons of ion temperatures derived from spectroscopic observations and calculated by ion-cyclotron models, for ions that span a broad range in q/m, would provide a rigorous test for such models. By using an ion-cyclotron model, we calculate the effective temperatures for 10 different ions that cover the range 0.16-0.37 in q/m. Effective temperatures correspond to unresolved thermal motions and wave motions. The good agreement between our calculations, based on the specific mechanism that we employed here (ion-cyclotron resonance) and on spectroscopic observations of effective temperatures in polar coronal holes, provides support that the above mechanism accounts for the energetics and kinematics of fast solar wind heavy ions. However, such an agreement does not prove that other potential mechanisms can be excluded.

**R10** *The Inability of Steady-Flow Models to Explain the Extreme-Ultraviolet Coronal Loops*, **S. Patsourakos** , J. A. Klimchuk, P. J. MacNeice, 2004, Astrophysical Journal, 603, 322

Recent observations from the Transition Region and Coronal Explorer (TRACE) and the EUV Imaging Telescope (EIT) show that warm (T 1-1.5 MK) EUV coronal loops in active regions generally have enhanced densities, enhanced pressure scale heights, and flat filter ratio (temperature) profiles in comparison with the predictions of static-equilibrium theory. It has been suggested that mass flows may explain these discrepancies. We investigate this conjecture using one-dimensional hydrodynamic simulations of steady flows in coronal loops. The flows are driven by asymmetric heating that decreases exponentially along the loop from one footpoint to the other. We find that a sufficiently large heating asymmetry can produce density enhancements consistent with a sizable fraction of the observed loops, but that the pressure scale heights are smaller than the corresponding gravitational scale heights, and that the filter ratio profiles are highly structured, in stark contrast to the observations. We conclude that most warm EUV loops cannot be explained by steady flows. It is thus likely that the heating in these loops is time dependent.

**R11** *A Model for Bright Extreme-Ultraviolet Knots in Solar Flare Loops*, **S. Patsourakos**, S. K. Antiochos, J. A. Klimchuk , 2004, Astrophysical Journal, 614, 1022

EUV observations often indicate the presence of bright knots in flare loops. The temperature of the knot plasma is of the order of 1 MK, and the knots themselves are usually localized somewhere near the loop tops. We propose a model in which the formation of EUV knots is due to the spatial structure of the nonflare active region heating. We present the results of a series of one-dimensional hydrodynamic, flare-loop simulations, which include both an impulsive flare heating and a background, active region heating. The simulations demonstrate that the formation of the observed knots depends critically on the spatial distribution of the background heating during the decay phase. In particular, the heating must be localized far from the loop apex and have a magnitude comparable to the local radiative losses of the cooling loop. Our results, therefore, provide strong

constraints on both coronal heating and postflare conditions.

**R12** *Coronal Loop Heating by Nanoflares: The Impact of the Field-aligned Distribution of the Heating on Loop Observables*, **S. Patsourakos** J. A. Klimchuk , 2005, Astrophysical Journal, 628,1023

Nanoflares occurring at subresolution strands with repetition times longer than the coronal cooling time are a promising candidate for coronal loop heating. To investigate the impact of the spatial distribution of the nanoflare heating on loop observables, we compute hydrodynamic simulations with several different spatial distributions (uniform, loop top, randomly localized, and footpoint). The outputs of the simulations are then used to calculate density and temperature diagnostics from synthetic TRACE and SXT observations. We find that the diagnostics depend only weakly on the spatial distribution of the heating and therefore are not especially useful for distinguishing among the different possibilities. Observations of the very high temperature plasmas that are present only in the earliest stages of nanoflares can shed more light on the field-aligned distribution of the heating.

**R13** *Non-thermal Spectral Line Broadening and the Nanoflare Model*, **S.Patsourakos**, J. A. Klimchuk, 2006, Astrophysical Journal, 647, 1452

A number of theoretical and observational considerations suggest that coronal loops are bundles of unresolved, impulsively heated strands. This "nanoflare" model, as it is sometimes called, predicts high-speed evaporative upflows, which might be revealed as nonthermal broadening of spectral line profiles. We have therefore generated synthetic line profile observations based on one-dimensional hydrodynamic simulations for comparison with actual observations. The predicted profiles for Ne VIII (770.4 Å), a transition region line, and Mg X (624.9 Å), a warm coronal line, have modest broadening that agrees well with existing observations. The predicted profiles for Fe XVII (254.87 Å), a hot line that will be observed by the Extreme Ultraviolet Imaging Spectrometer (EIS) on the Solar-B mission, are somewhat broader and are also consistent with the limited number of hot line observations that are currently available. Moreover, depending on the properties of the assumed nanoflare and other parameters of the simulation, the Fe XVII profile can have distinctive enhancements in the line wing. This indicates a powerful diagnostic capability that can be exploited once Solar-B is launched.

**R14** *The Quiet Sun Network at Subarcsecond Resolution: VAULT Observations and Radiative Transfer Modeling of Cool Loops*,**S. Patsourakos**,P. Gouttebroze, P., A. Vourlidas, 2007, Astrophysical Journal, 664, 1214

One of the most enigmatic regions of the solar atmosphere is the transition region (TR), corresponding to plasmas with temperatures intermediate of the cool, few thousand K, chromosphere and the hot, few million K, corona. The traditional view is that the TR emission originates from a thin thermal interface in hot coronal structures, connecting their chromosphere with their corona. This paradigm fails badly for cool plasmas ( $T < 10^5$ K), since it predicts emission orders of magnitude less than what it is observed. It was therefore proposed that the "missing" TR emission could originate from tiny, isolated from the hot corona, cool loops at TR temperatures. A major problem in investigating this proposal is the very small sizes of the hypothesized cool loops. Here, we report the first spatially resolved observations of subarcsecond-scale looplike structures seen in the Ly $\alpha$= line made by the Very High Angular Resolution Ultraviolet Telescope (VAULT). The subarcsecond ( 0.3") resolution of VAULT allows us to directly view and resolve looplike structures in the quiet Sun network. We compare the observed intensities of these structures with

simplified radiative transfer models of cool loops. The reasonable agreement between the models and the observations indicates that an explanation of the observed fine structure in terms of cool loops is plausible.

**R15** *The Cross-Field Thermal Structure of Coronal Loops from Triple-Filter TRACE Observations*, **S. Patsourakos**, J. A. Klimchuk, 2007, Astrophysical Journal, 667, 591

The highly suppressed thermal transport across the magnetic field in the solar corona makes the determination of the cross-field thermal distribution within coronal loops a powerful diagnostic of the properties of the heating process itself. The cross-field thermal structure is currently being strongly debated. Spectroscopic observations with high temperature fidelity but low spatial resolution indicate that some observed loops are multithermal, whereas imaging observations with high spatial resolution but low temperature fidelity indicate more isothermal conditions. We report here on triple filter observations of coronal loops made by the Transition Region and Coronal Explorer (TRACE), which has the best spatial resolution currently available. We tested the isothermal hypothesis using the emission measure loci technique and found that the loops are consistent with an isothermal plasma near 1.5 MK only if a generous estimate of the photometric uncertainties is used. A more restrictive estimate based on discussions with the TRACE experimenters rules out the isothermal hypothesis. The observations are much better explained by a multithermal plasma with significant emission measure throughout the range 1-3 MK. The details of the emission measure distribution are not well defined, however. Future subarcsecond spectroscopic observations covering a wide range of temperatures are the most promising means of unlocking the thermal structure of the corona.

**R16** *STEREO SECCHI Stereoscopic Observations Constraining the Initiation of Polar Coronal Jets*, **S. Patsourakos**, E. Pariat, A. Vourlidas, S. K. Antiochos, J. P. Wuelser, 2008, Astrophysical Journal, 680,73

We report on the first stereoscopic observations of polar coronal jets made by the EUVI/SECCHI imagers on board the twin STEREO spacecraft. The significantly separated viewpoints ( 11 degrees) allowed us to infer the 3D dynamics and morphology of a well-defined EUV coronal jet for the first time. Triangulations of the jet's location in simultaneous image pairs led to the true 3D position and thereby its kinematics. Initially the jet ascends slowly at 10-20 km/s and then, after an apparent "jump" takes place, it accelerates impulsively to velocities exceeding 300 km/s with accelerations exceeding the solar gravity. Helical structure is the most important geometrical feature of the jet which shows evidence of untwisting. The jet structure appears strikingly different from each of the two STEREO viewpoints: face-on in one viewpoint and edge-on in the other. This provides conclusive evidence that the observed helical structure is real and does not result from possible projection effects of single-viewpoint observations. The clear demonstration of twisted structure in polar jets compares favorably with synthetic images from a recent MHD simulation of jets invoking magnetic untwisting as their driving mechanism. Therefore, the latter can be considered as a viable mechanism for the initiation of polar jets.

**R17** *Highly Efficient Modeling of Dynamic Coronal Loops*, J. A., Klimchuk, **S. Patsourakos**, P. J. Cargill, 2008, Astrophysical Journal,682, 1351

Observational and theoretical evidence suggests that coronal heating is impulsive and occurs on very small cross-field spatial scales. A single coronal loop could contain a hundred or more individual strands that are heated quasi-independently by nanoflares. It is therefore an enormous undertaking to model an entire active region or the global corona.

Three-dimensional MHD codes have inadequate spatial resolution, and one-dimensional (1D) hydrodynamic codes are too slow to simulate the many thousands of elemental strands that must be treated in a reasonable representation. Fortunately, thermal conduction and flows tend to smooth out plasma gradients along the magnetic field, so zero-dimensional (0D) models are an acceptable alternative. We have developed a highly efficient model called "enthalpy-based thermal evolution of loops" (EBTEL), which accurately describes the evolution of the average temperature, pressure, and density along a coronal strand. It improves significantly on earlier models of this type-in accuracy, flexibility, and capability. It treats both slowly varying and highly impulsive coronal heating; it provides the time-dependent differential emission measure distribution, DEM(T), at the transition region footpoints; and there are options for heat flux saturation and nonthermal electron beam heating. EBTEL gives excellent agreement with far more sophisticated 1D hydrodynamic simulations despite using 4 orders of magnitude less computing time. It promises to be a powerful new tool for solar and stellar studies.

**R18** *Static and Impulsive Models of Solar Active Regions*, **S. Patsourakos**, J. A. Klimchuk, 2008, Astrophysical Journal, 689, 1406

The physical modeling of active regions (ARs) and of the global corona is receiving increasing interest lately. Recent attempts to model ARs using static equilibrium models were quite successful in reproducing AR images of hot soft X-ray (SXR) loops. They however failed to predict the bright extreme-ultraviolet (EUV) warm loops permeating ARs: the synthetic images were dominated by intense footpoint emission. We demonstrate that this failure is due to the very weak dependence of loop temperature on loop length which cannot simultaneously account for both hot and warm loops in the same AR. We then consider time-dependent AR models based on nanoflare heating. We demonstrate that such models can simultaneously reproduce EUV and SXR loops in ARs. Moreover, they predict radial intensity variations consistent with the localized core and extended emissions in SXR and EUV AR observations, respectively. We finally show how the AR morphology can be used as a gauge of the properties (duration, energy, spatial dependence, and repetition time) of the impulsive heating.

**R19** *Spectroscopic Observations of Hot Lines Constraining Coronal Heating in Solar Active Regions*, **S. Patsourakos**, J. A. Klimchuk, 2009, Astrophysical Journal, 696, 760

Extreme-ultraviolet observations of warm coronal loops suggest that they are bundles of unresolved strands that are heated impulsively to high temperatures by nanoflares. The plasma would then have the observed properties (e.g., excess density compared with static equilibrium) when it cools into the 1-2MK range. If this interpretation is correct, then very hot emission should be present outside of proper flares. It is predicted to be very faint, however. A critical element for proving or refuting this hypothesis is the existence of hot, yet faint plasmas which should be at amounts predicted by impulsive heating models. We report on the first comprehensive spectroscopic study of hot plasmas in active regions (ARs). Data from the Extreme-ultraviolet Imaging Spectrometer on Hinode were used to construct emission measure (EM) distributions in quiescent ARs in the 1-5 MK temperature range. The distributions are flat or slowly increasing up to approximately 3 MK and then fall off rapidly at higher temperatures. We show that AR models based on impulsive heating can reproduce the observed EM distributions relatively well. Our results provide strong new evidence that coronal heating is impulsive in nature.

**R20** *"Extreme Ultraviolet Waves" are Waves: First Quadrature Observations of an Extreme*

*Ultraviolet Wave from STEREO*, **S. Patsourakos**, A. Vourlidas, 2009, Astrophysical Journal, 700, 182

The nature of coronal mass ejection (CME)-associated low corona propagating disturbances, "extreme ultraviolet (EUV) waves," has been controversial since their discovery by EIT on SOHO. The low-cadence, single-viewpoint EUV images and the lack of simultaneous inner corona white-light observations have hindered the resolution of the debate on whether they are true waves or just projections of the expanding CME. The operation of the twin EUV imagers and inner corona coronagraphs aboard STEREO has improved the situation dramatically. During early 2009, the STEREO Ahead (STA) and Behind (STB) spacecrafts observed the Sun in quadrature having a 90-degree angular separation. An EUV wave and CME erupted from active region 11012, on February 13, when the region was exactly at the limb for STA and hence at disk center for STB. The STEREO observations capture the development of a CME and its accompanying EUV wave not only with high cadence but also in quadrature. The resulting unprecedented data set allowed us to separate the CME structures from the EUV wave signatures and to determine without doubt the true nature of the wave. It is a fast-mode MHD wave after all.

**R21** *No Trace Left Behind: STEREO Observation of a Coronal Mass Ejection Without Low Coronal Signatures*, E. Robbrecht, **S. Patsourakos**, A. Vourlidas, 2009, Astrophysical Journal, 701, 283

The availability of high-quality synoptic observations of the extreme-ultraviolet (EUV) and visible corona during the SOHO mission has advanced our understanding of the low corona manifestations of coronal mass ejections (CMEs). The EUV imager/white light coronagraph connection has been proven so powerful, it is routinely assumed that if no EUV signatures are present when a CME is observed by a coronagraph, then the event must originate behind the visible limb. This assumption carries strong implications for space weather forecasting but has not been put to the test. This paper presents the first detailed analysis of a frontside, large-scale CME that has no obvious counterparts in the low corona as observed in EUV and H$\alpha$ wavelengths. The event was observed by the SECCHI instruments onboard the STEREO mission. The COR2A coronagraph observed a slow flux-rope-type CME, while an extremely faint partial halo was observed in COR2B. The event evolved very slowly and is typical of the streamer-blowout CME class. EUVI A 171 Åimages show a concave feature above the east limb, relatively stable for about two days before the eruption, when it rises into the coronagraphic fields and develops into the core of the CME. None of the typical low corona signatures of a CME (flaring, EUV dimming, filament eruption, waves) were observed in the EUVI B images, which we attribute to the unusually large height from which the flux rope lifted off. This interpretation is supported by the CME mass measurements and estimates of the expected EUV dimming intensity. Only thanks to the availability of the two viewpoints we were able to identify the likely source region. The event originated along a neutral line over the quiet-Sun. No active regions were present anywhere on the visible (from STEREO B) face of the disk. Leaving no trace behind on the solar disk, this observation shows unambiguously that a CME eruption does not need to have clear on-disk signatures. Also it sheds light on the question of "mystery" geomagnetic storms, storms without clear solar origin (formerly called problem storms). We discuss the implications for space weather monitoring. Preliminary inspection of STEREO data indicates that events like this are not uncommon, particularly during the ongoing period of deep solar minimum.

**R22** *Estimating the Chromospheric Absorption of Transition Region Moss Emission*, D. De

Pontieu, V. Hansteen, S. W. McIntosh, **S. Patsourakos**, 2009, Astrophysical Journal, 702, 1016

Many models for coronal loops have difficulty explaining the observed EUV brightness of the transition region, which is often significantly less than theoretical models predict. This discrepancy has been addressed by a variety of approaches including filling factors and time-dependent heating, with varying degrees of success. Here, we focus on an effect that has been ignored so far: the absorption of EUV light with wavelengths below 912 Å by the resonance continua of neutral hydrogen and helium. Such absorption is expected to occur in the low-lying transition region of hot, active region loops that is colocated with cool chromospheric features and called "moss" as a result of the reticulated appearance resulting from the absorption. We use cotemporal and cospatial spectroheliograms obtained with the Solar and Heliospheric Observatory/SUMER and Hinode/EIS of Fe XII 1242 Å, 195 Å, and 186.88 Å, and compare the density determination from the 186/195 Å line ratio to that resulting from the 195/1242 Å line ratio. We find that while coronal loops have compatible density values from these two line pairs, upper transition region moss has conflicting density determinations. This discrepancy can be resolved by taking into account significant absorption of 195 Å emission caused by the chromospheric inclusions in the moss. We find that the amount of absorption is generally of the order of a factor of 2. We compare to numerical models and show that the observed effect is well reproduced by three-dimensional radiative MHD models of the transition region and corona. We use STEREO A/B data of the same active region and find that increased angles between line of sight and local vertical cause additional absorption. Our determination of the amount of chromospheric absorption of TR emission can be used to better constrain coronal heating models.

**R23** *What Is the Nature of EUV Waves? First STEREO 3D Observations and Comparison with Theoretical Models*, **S. Patsourakos**, A. Vourlidas, Y. M. Wang, G. Stenborg, A. Thernisien, 2009, Solar Physics, 259, 49

One of the major discoveries of the Extreme ultraviolet Imaging Telescope (EIT) on SOHO was the intensity enhancements propagating over a large fraction of the solar surface. The physical origin(s) of the so-called EIT waves is still strongly debated with either wave (primarily fast-mode MHD waves) or nonwave (pseudo-wave) interpretations. The difficulty in understanding the nature of EUV waves lies in the limitations of the EIT observations that have been used almost exclusively for their study. They suffer from low cadence and single temperature and viewpoint coverage. These limitations are largely overcome by the SECCHI/EUVI observations onboard the STEREO mission. The EUVI telescopes provide high-cadence, simultaneous multitemperature coverage and two well-separated viewpoints. We present here the first detailed analysis of an EUV wave observed by the EUVI disk imagers on 7 December 2007 when the STEREO spacecraft separation was 45 degrees. Both a small flare and a coronal mass ejection (CME) were associated with the wave. We also offer the first comprehensive comparison of the various wave interpretations against the observations. Our major findings are as follows: (1) High-cadence (2.5-minute) 171 Å images showed a strong association between expanding loops and the wave onset and significant differences in the wave appearance between the two STEREO viewpoints during its early stages; these differences largely disappeared later; (2) the wave appears at the active region periphery when an abrupt disappearance of the expanding loops occurs within an interval of 2.5 minutes; (3) almost simultaneous images at different temperatures showed that the wave was most visible in the 1 - 2 MK range and

almost invisible in chromospheric/transition region temperatures; (4) triangulations of the wave indicate it was rather low lying ($\approx$ 90 Mm above the surface); (5) forward-fitting of the corresponding CME as seen by the COR1 coronagraphs showed that the projection of the best-fit model on the solar surface was inconsistent with the location and size of the co-temporal EUV wave; and (6) simulations of a fast-mode wave were found in good agreement with the overall shape and location of the observed wave. Our findings give significant support for a fast-mode interpretation of EUV waves and indicate that they are probably triggered by the rapid expansion of the loops associated with the CME.

**R24** *Characteristics of EUV Coronal Jets Observed with STEREO/SECCHI*, G. Nistico, V. Bothmer, **S. Patsourakos**, G. Zimbardo, 2009, Solar Physics, 259, 87

In this paper we present the first comprehensive statistical study of EUV coronal jets observed with the SECCHI (Sun Earth Connection Coronal and Heliospheric Investigation) imaging suites of the two STEREO spacecraft. A catalogue of 79 polar jets is presented, identified from simultaneous EUV and white-light coronagraph observations, taken during the time period March 2007 to April 2008, when solar activity was at a minimum. The twin spacecraft angular separation increased during this time interval from 2 to 48 degrees. The appearances of the coronal jets were always correlated with underlying small-scale chromospheric bright points. A basic characterization of the morphology and identification of the presence of helical structure were established with respect to recently proposed models for their origin and temporal evolution. Though each jet appeared morphologically similar in the coronagraph field of view, in the sense of a narrow collimated outward flow of matter, at the source region in the low corona the jet showed different characteristics, which may correspond to different magnetic structures. A classification of the events with respect to previous jet studies shows that amongst the 79 events there were 37 Eiffel tower-type jet events, commonly interpreted as a small-scale ($\sim$ 35 arc sec) magnetic bipole reconnecting with the ambient unipolar open coronal magnetic fields at its loop tops, and 12 lambda-type jet events commonly interpreted as reconnection with the ambient field happening at the bipole footpoints. Five events were termed micro-CME-type jet events because they resembled the classical coronal mass ejections (CMEs) but on much smaller scales. The remaining 25 cases could not be uniquely classified. Thirty-one of the total number of events exhibited a helical magnetic field structure, indicative for a torsional motion of the jet around its axis of propagation. A few jets are also found in equatorial coronal holes. In this study we present sample events for each of the jet types using both, STEREO A and STEREO B, perspectives. The typical lifetimes in the SECCHI/EUVI ( Extreme UltraViolet Imager) field of view between 1.0 to 1.7 R sun and in SECCHI/COR1 field of view between 1.4 to 4 R sun are obtained, and the derived speeds are roughly estimated. In summary, the observations support the assumption of continuous small-scale reconnection as an intrinsic feature of the solar corona, with its role for the heating of the corona, particle acceleration, structuring and acceleration of the solar wind remaining to be explored in more detail in further studies.

**R25** *Extreme Ultraviolet Observations and Analysis of Micro-Eruptions and Their Associated Coronal Waves*, O. Podladchikova, A. Vourlidas, R. A. Van der Linden, J. P., Wuslser, **S. Patsourakos**, 2010, Astrophysical Journal, 709, 369

The Solar Terrestrial Relations Observatory EUV telescopes have uncovered small-scale eruptive events, tentatively referred to as "mini-CMEs" because they exhibit morphologies similar to large-scale coronal mass ejections (CMEs). Coronal waves and widespread diffuse dimmings followed by the expansion of the coronal waves are the most brightly

manifestations of large-scale CMEs. The high temporal and spatial resolution of the EUV data allows us to detect and analyze these eruptive events, to resolve their fine structure, and to show that the observed "mini-waves" have a strong similarity to the large-scale "EIT' waves. Here, we analyze a micro-event observed on 2007 October 17 by the Sun Earth Connection Coronal and Heliospheric Investigation EUV Imager (EUVI) in 171 Å (Fe IX) with a 2.5 minute cadence. The mini-CME differs from its large-scale counterparts by having smaller geometrical size, a shorter lifetime, and reduced intensity of coronal wave and dimmings. The small-scale coronal wave develops from micro-flaring sites and propagate up to a distance of 40000 km in a wide angular sector of the quiet Sun over 20 minutes. The area of the small-scale dimming is two orders of magnitude smaller than for large-scale events. The average speed of the small-scale coronal wave studied is 14 km/s. Our observations give strong indications that small-scale EUV coronal waves associated with the micro-eruptions propagate in the form of slow mode waves almost perpendicular to the background magnetic field.

**R26** *The Structure and Dynamics of the Upper Chromosphere and Lower Transition Region as Revealed by the Subarcsecond VAULT Observations*, A. Vourlidas, B. Sanchez Andrade-Nuno, E. Landi, **S. Patsourakos**, L. Teriaca, U. Schuhle, C. M. Korendyke, I. Nestoras, 2010, Solar Physics, 261, 53

The Very high Angular resolution ULtraviolet Telescope (VAULT) is a sounding rocket payload built to study the crucial interface between the solar chromosphere and the corona by observing the strongest line in the solar spectrum, the Ly $\alpha$ line at 1216 Å. In two flights, VAULT succeeded in obtaining the first ever subarcsecond ( $0.5''$ ) images of this region with high sensitivity and cadence. Detailed analyses of those observations contributed significantly to new ideas about the nature of the transition region. Here, we present a broad overview of the Ly $\alpha$ atmosphere as revealed by the VAULT observations and bring together past results and new analyses from the second VAULT flight to create a synthesis of our current knowledge of the high-resolution Ly $\alpha$ Sun. We hope that this work will serve as a good reference for the design of upcoming Ly $\alpha$ telescopes and observing plans.

**R27** *Observational features of equatorial coronal hole jets*, G. Nistico, V. Bothmer, **S. Patsourakos**, G. Zimbardo, 2010, Annales Geophysicae, 28, 687

Collimated ejections of plasma called "coronal hole jets" are commonly observed in polar coronal holes. However, such coronal jets are not only a specific features of polar coronal holes but they can also be found in coronal holes appearing at lower heliographic latitudes. In this paper we present some observations of "equatorial coronal hole jets" made up with data provided by the STEREO/SECCHI instruments during a period comprising March 2007 and December 2007. The jet events are selected by requiring at least some visibility in both COR1 and EUVI instruments. We report 15 jet events, and we discuss their main features. For one event, the uplift velocity has been determined as about 200 km/s, while the deceleration rate appears to be about 0.11 $kms^{-2}$ less than solar gravity. The average jet visibility time is about 30 min, consistent with jet observed in polar regions. On the basis of the present dataset, we provisionally conclude that there are not substantial physical differences between polar and equatorial coronal hole jets.

**R28** *Comprehensive Analysis of Coronal Mass Ejection Mass and Energy Properties Over a Full Solar Cycle*, A. Vourlidas, R. A. Howard, E. Esfandiari, **S. Patsourakos**, S. Yashiro, G. Michalek, 2010, Astrophysical Journal, 722, 1522

The LASCO coronagraphs, in continuous operation since 1995, have observed the evolution

of the solar corona and coronal mass ejections (CMEs) over a full solar cycle with high-quality images and regular cadence. This is the first time that such a data set becomes available and constitutes a unique resource for the study of CMEs. In this paper, we present a comprehensive investigation of the solar cycle dependence on the CME mass and energy over a full solar cycle (1996-2009) including the first in-depth discussion of the mass and energy analysis methods and their associated errors. Our analysis provides several results worthy of further studies. It demonstrates the possible existence of two event classes: "normal" CMEs reaching constant mass for >10 Rsun and "pseudo"-CMEs which disappear in the C3 field of view. It shows that the mass and energy properties of CME reach constant levels and therefore should be measured only above $\sim$ 10 Rsun. The mass density of CMEs varies relatively little (< order of magnitude) suggesting that the majority of the mass originates from a small range in coronal heights. We find a sudden reduction in the CME mass in mid-2003 which may be related to a change in the electron content of the large-scale corona and we uncover the presence of a 6 month periodicity in the ejected mass from 2003 onward.

**R29** *Toward understanding the early stages of an impulsively accelerated coronal mass ejection. SECCHI observations*, **S. Patsourakos**, A. Vourlidas, B. Kliem, 2010, Astronomy and Astrophysics, 522, 100

Context. The expanding magnetic flux in coronal mass ejections (CMEs) often forms a cavity. Studies of CME cavities have so far been limited to the pre-event configuration to evolved CMEs at great heights, and to two-dimensional imaging data. Aims: Quantitative analysis of three-dimensional cavity evolution at CME onset can reveal information that is relevant to the genesis of the eruption. Methods: A spherical model was simultaneously fit to Solar Terrestrial Relations Observatory (STEREO) Extreme Ultraviolet Imager (EUVI) and Inner Coronagraph (COR1) data of an impulsively accelerated CME on 25 March 2008, which displays a well-defined extreme ultraviolet (EUV) and white-light cavity of nearly circular shape already at low heights h $\sim$ 0.2 Rsun. The center height h(t) and radial expansion r(t) of the cavity were obtained in the whole height range of the main acceleration. We interpret them as the axis height and as a quantity proportional to the minor radius of a flux rope. Results: The three-dimensional expansion of the CME exhibits two phases in the course of its main upward acceleration. From the first h and r data points, taken shortly after the onset of the main acceleration, the erupting flux shows an overexpansion compared to its rise, as expressed by the decrease in the aspect ratio from $\kappa = h/r \sim 3$ to $\kappa \sim$ (1.5-2). This phase is approximately coincident with the impulsive rise in the acceleration and is followed by a phase of very gradual change in the aspect ratio (a nearly self-similar expansion) toward $\kappa \sim 2.5$ at h $\sim$ 10 Rsun. The initial overexpansion of the CME cavity can be caused by flux conservation around a rising flux rope of decreasing axial current and by the addition of flux to a growing, or by even newly formed, flux rope by magnetic reconnection. Further analysis will be required to decide which of these contributions is dominant. The data also suggest that the horizontal component of the impulsive cavity expansion (parallel to the solar surface) triggers the associated EUV wave, which subsequently detaches from the CME volume.

**R30** *The Genesis of an Impulsive Coronal Mass Ejection Observed at Ultra-high Cadence by AIA on SDO*, **S. Patsourakos**, A. Vourlidas, G. Stenborg, 2010, Astrophysical Journal, 724, 188

The study of fast, eruptive events in the low solar corona is one of the science objectives of the Atmospheric Imaging Assembly (AIA) imagers on the recently launched Solar

Dynamics Observatory (SDO), which take full disk images in 10 wavelengths with arcsecond resolution and 12 s cadence. We study with AIA the formation of an impulsive coronal mass ejection (CME) which occurred on 2010 June 13 and was associated with an M1.0 class flare. Specifically, we analyze the formation of the CME EUV bubble and its initial dynamics and thermal evolution in the low corona using AIA images in three wavelengths (171 Å, 193 Å, and 211 Å). We derive the first ultra-high cadence measurements of the temporal evolution of the CME bubble aspect ratio (=bubble height/bubble radius). Our main result is that the CME formation undergoes three phases: it starts with a slow self-similar expansion followed by a fast but short-lived (∼70 s) period of strong lateral overexpansion which essentially creates the CME. Then the CME undergoes another phase of self-similar expansion until it exits the AIA field of view. During the studied interval, the CME height-time profile shows a strong, short-lived, acceleration followed by deceleration. The lateral overexpansion phase coincides with the deceleration phase. The impulsive flare heating and CME acceleration are closely coupled. However, the lateral overexpansion of the CME occurs during the declining phase and is therefore not linked to flare reconnection. In addition, the multi-thermal analysis of the bubble does not show significant evidence of temperature change.

**R31** *Evidence for a current sheet forming in the wake of a coronal mass ejection from multi-viewpoint coronagraph observations*, **S. Patsourakos**, A. Vourlidas, 2011, Astronomy and Astrophysics, 525, 27

Context. Ray-like features observed by coronagraphs in the wake of coronal mass ejections (CMEs) are sometimes interpreted as the white light counterparts of current sheets (CSs) produced by the eruption. The 3D geometry of these ray-like features is largely unknown and its knowledge should clarify their association to the CS and place constraints on CME physics and coronal conditions. Aims: If these rays are related to field relaxation behind CMEs, therefore representing current sheets, then they should be aligned to the CME axis. With this study we test these important implications for the first time. Methods: An example of such a post-CME ray was observed by various coronagraphs, including these of the Sun Earth Connection Coronal and Heliospheric investigation (SECCHI) onboard the Solar Terrestrial Relations Observatory (STEREO) twin spacecraft and the Large Angle Spectrometric Coronagraph (LASCO) onboard the Solar and Heliospheric Observatory (SOHO). The ray was observed in the aftermath of a CME which occurred on 9 April 2008. The twin STEREO spacecraft were separated by about 48 degrees on that day. This significant separation combined with a "third eye" view supplied by LASCO allow for a truly multi-viewpoint observation of the ray and of the CME. We applied 3D forward geometrical modeling to the CME and to the ray as simultaneously viewed by SECCHI-A and B and by SECCHI-A and LASCO, respectively. Results: We found that the ray can be approximated by a rectangular slab, nearly aligned with the CME axis, and much smaller than the CME in both terms of thickness and depth (∼0.05 and 0.15 Rsun respectively). The ray electron density and temperature were substantially higher than their values in the ambient corona. We found that the ray and CME are significantly displaced from the associated post-CME flaring loops. Conclusions: The properties and location of the ray are fully consistent with the expectations of the standard CME theories for post-CME current sheets. Therefore, our multi-viewpoint observations supply strong evidence that the observed post-CME ray is indeed related to a post-CME current sheet.

**R32** *Determination of temperature maps of EUV coronal hole jets*, G. Nistico, **S. Patsourakos**, V. Bothmer, G. Zimbardo, 2011, Advances in Space Research, 48, 1490

Coronal hole jets are fast ejections of plasma occurring within coronal holes, observed at Extreme-UltraViolet (EUV) and X-ray wavelengths. Recent observations of jets by the STEREO and Hinode missions show that they are transient phenomena which occur at much higher rates than large-scale impulsive phenomena like flares and Coronal Mass Ejections (CMEs). In this paper we describe some typical characteristics of coronal jets observed by the SECCHI instruments of STEREO spacecraft. We show an example of 3D reconstruction of the helical structure for a south pole jet, and present how the angular distribution of the jet position angles changes from the Extreme-UltraViolet-Imager (EUVI) field of view to the CORonagraph1 (COR1) (height $\sim$ 2.0 Rsun heliocentric distance) field of view. Then we discuss a preliminary temperature determination for the jet plasma by using the filter ratio method at 171 and 195 Åand applying a technique for subtracting the EUV background radiation. The results show that jets are characterized by electron temperatures ranging between 0.8 and 1.3 MK. We present the thermal structure of the jet as temperature maps and we describe its thermal evolution.

**R33** *LEMUR: Large European module for solar Ultraviolet Research*, Teriaca, L. Andretta, V. Auchère, F., Brown, C. M., Buchlin, E., Cauzzi, G., Culhane, J. L., Curdt, W., Davila, J. M., Del Zanna, G., Doschek, G. A., Fineschi, S. Fludra, A., Gallagher, P. T., Green, L., Harra, L. K., Imada, S., Innes, D., Kliem, B., Korendyke, C., Mariska, J. T., Martínez-Pillet, V., Parenti, S., **Patsourakos S.**, Peter, H., Poletto, L., Rutten, R. J., Schühle, U., Siemer, M., Shimizu, T., Socas-Navarro, H., Solanki, S. K., Spadaro, D., Trujillo-Bueno, J., Tsuneta, S., Dominguez, S. V., Vial, J.-C., Walsh, R., Warren, H. P., Wiegelmann, T., Winter, B., Young, P., 2012 Experimental Astronomy, 34, 273

The solar outer atmosphere is an extremely dynamic environment characterized by the continuous interplay between the plasma and the magnetic field that generates and permeates it. Such interactions play a fundamental role in hugely diverse astrophysical systems, but occur at scales that cannot be studied outside the solar system. Understanding this complex system requires concerted, simultaneous solar observations from the visible to the vacuum ultraviolet (VUV) and soft X-rays, at high spatial resolution (between 0.1" and 0.3"), at high temporal resolution (on the order of 10 s, i.e., the time scale of chromospheric dynamics), with a wide temperature coverage (0.01 MK to 20 MK, from the chromosphere to the flaring corona), and the capability of measuring magnetic fields through spectropolarimetry at visible and near-infrared wavelengths. Simultaneous spectroscopic measurements sampling the entire temperature range are particularly important. These requirements are fulfilled by the Japanese Solar-C mission (Plan B), composed of a spacecraft in a geosynchronous orbit with a payload providing a significant improvement of imaging and spectropolarimetric capabilities in the UV, visible, and near-infrared with respect to what is available today and foreseen in the near future. The Large European Module for solar Ultraviolet Research (LEMUR), described in this paper, is a large VUV telescope feeding a scientific payload of high-resolution imaging spectrographs and cameras. LEMUR consists of two major components: a VUV solar telescope with a 30 cm diameter mirror and a focal length of 3.6 m, and a focal-plane package composed of VUV spectrometers covering six carefully chosen wavelength ranges between 170 Å and 1270 Å. The LEMUR slit covers 280" on the Sun with 0.14" per pixel sampling. In addition, LEMUR is capable of measuring mass flows velocities (line shifts) down to 2 km/s or better. LEMUR has been proposed to ESA as the European contribution to the Solar C mission.

**R34** *On the Role of the Background Overlying Magnetic Field in Solar Eruptions*, A. Nindos,

**S. Patsourakos**, T. Wiegelmann, 2012, Astrophysical Journal, 748, 6

The primary constraining force that inhibits global solar eruptions is provided by the overlying background magnetic field. Using magnetic field data from both the Helioseismic and Magnetic Imager aboard the Solar Dynamics Observatory and the spectropolarimeter of the Solar Optical Telescope aboard Hinode, we study the long-term evolution of the background field in active region AR11158 that produced three major coronal mass ejections (CMEs). The CME formation heights were determined using EUV data. We calculated the decay index - $-(z/B)(\partial B)/(\partial z)$ of the magnetic field B (i.e., how fast the field decreases with height, $z$) related to each event from the time of the active region emergence until well after the CMEs. At the heights of CME formation, the decay indices were 1.1-2.1. Prior to two of the events, there were extended periods (of more than 23 hr) where the related decay indices at heights above the CME formation heights either decreased (up to -15 %) or exhibited small changes. The decay index related to the third event increased (up to 118 %) at heights above 20 Mm within an interval that started 64 hr prior to the CME. The magnetic free energy and the accumulated helicity into the corona contributed the most to the eruptions by their increase throughout the flux emergence phase (by factors of more than five and more than two orders of magnitude, respectively). Our results indicate that the initiation of eruptions does not depend critically on the temporal evolution of the variation of the background field with height.

**R35** *On the Nature and Genesis of EUV Waves: A Synthesis of Observations from SOHO, STEREO, SDO, and Hinode*, **S. Patsourakos**, A. Vourlidas, 2012, Solar Physics, 281, 187

A major, albeit serendipitous, discovery of the SOlar and Heliospheric Observatory mission was the observation by the Extreme Ultraviolet Telescope (EIT) of large-scale extreme ultraviolet (EUV) intensity fronts propagating over a significant fraction of the Sun's surface. These so-called EIT or EUV waves are associated with eruptive phenomena and have been studied intensely. However, their wave nature has been challenged by non-wave (or pseudo-wave) interpretations and the subject remains under debate. A string of recent solar missions has provided a wealth of detailed EUV observations of these waves bringing us closer to resolving the question of their nature. With this review, we gather the current state-of-the-art knowledge in the field and synthesize it into a picture of an EUV wave driven by the lateral expansion of the CME. This picture can account for both wave and pseudo-wave interpretations of the observations, thus resolving the controversy over the nature of EUV waves to a large degree but not completely. We close with a discussion on several remaining open questions in the field of EUV waves research.

**R36** *Direct Evidence for a Fast CME Driven by the Prior Formation and Subsequent Destabilization of a Magnetic Flux Rope*, **S. Patsourakos**, A. Vourlidas, G. Stenborg, 2013, ApJ, 764,125

Magnetic flux ropes play a central role in the physics of Coronal Mass Ejections (CMEs). Although a flux rope topology is inferred for the majority of coronagraphic observations of CMEs, a heated debate rages on whether the flux ropes pre-exist or whether they are formed on-the-fly during the eruption. Here, we present a detailed analysis of Extreme Ultraviolet observations of the formation of a flux rope during a confined flare followed about seven hours later by the ejection of the flux rope and an eruptive flare. The two flares occurred during 18 and 19 July 2012. The second event unleashed a fast ($> 1000$ km/s) CME. We present the first direct evidence of a fast CME driven by the prior formation

and destabilization of a coronal magnetic flux rope formed during the confined flare on 18 July.

**R37** *Spectral diagnostic of a micro-flare. Evidences of resonant scattering in C iv 1548 Å, 1550 Å lines*, C. Gontikakis, A. R. Winebarger, **S. Patsourakos**, 2013, Astronomy and Astrophysics, 550, 16

We study a microflare, classified as a GOES-A1 after background subtraction, which was observed in active region NOAA 8541 on May 15, 1999. We used TRACE filtergrams to study the morphology and time evolution. SUMER spectral lines are used to diagnose the chromospheric S III 1533 Å), transition region (C IV 1548, 1550 Å), and coronal (Ne VIII 770 Å) plasma. In the 171 Å and 195 Å filtergrams, we measure apparent mass motions along two small loops composing the microflare from the East toward the West footpoints. In SUMER, the microflare is detected as a small (47 $Mm^2$) bright area at the west footpoints of the TRACE loops. The spectral profiles recorded over the bright area are complex. The S III 1533 Å line is self reversed due to opacity and the coronal line profile is composed of two Gaussian components, one of them being systematically redshifted. The C IV 1548 Å and 1550 Å profiles are badly distorted due to the temporary depression of the detector local gain caused by the very high count-rates reached in the flaring region and we can only confirm the presence of strong blue shifts of $\simeq -200$ km/s. Few, non affected profiles show two spectral components. In the north part of the bright area, all SUMER spectral lines have at least one blueshifted spectral component. In the south region of the bright area the spectral lines are redshifted. Adjacent to the microflare we measure, for the first time on the solar disk, an intensity ratio of the 1548 Å line to 1550 Å line with values of 3 to 4 indicating that, resonance scattering prevails in the lines formation. Moreover, the scattering region is found to be co-spatial to a solar pore. The blueshifts in the footpoints of the microflare and the apparent mass motions observed with TRACE can be explained by a gentle chromospheric evaporation triggered by the microflare. The redshifted spectral components can be explained as cooling material falling back on the solar surface. The importance of resonant scattering, can be explained by the small electron density expected in the transition region of a solar pore, combined with the high photon flux coming from the nearby microflare.

**R38** *Combining Particle Acceleration and Coronal Heating via Data-Constrained Calculations of Nanoflares in Coronal Loops*, C. Gontikakis, **S. Patsourakos**, C. Efthymiopoulos, A. Anastasiadis, M. K. Georgoulis, 2013, Astrophysical Journal, 771, 126

We model nanoflare heating of extrapolated active-region coronal loops via the acceleration of electrons and protons in Harris-type current sheets. The kinetic energy of the accelerated particles is estimated using semi-analytical and test-particle-tracing approaches. Vector magnetograms and photospheric Doppler velocity maps of NOAA active region 09114, recorded by the Imaging Vector Magnetograph, were used for this analysis. A current-free field extrapolation of the active-region corona was first constructed. The corresponding Poynting fluxes at the footpoints of 5000 extrapolated coronal loops were then calculated. Assuming that reconnecting current sheets develop along these loops, we utilized previous results to estimate the kinetic energy gain of the accelerated particles. We related this energy to nanoflare heating and macroscopic loop characteristics. Kinetic energies of 0.1-8 keV (for electrons) and 0.3-470 keV (for protons) were found to cause heating rates ranging from $10^{-6}$ to 1 $ergs^{-1}cm^{-3}$. Hydrodynamic simulations show that such heating rates can sustain plasma in coronal conditions inside the loops and generate plasma thermal distributions that are consistent with active-region observations. We concluded the analysis

by computing the form of X-ray spectra generated by the accelerated electrons using the thick-target approach. These spectra were found to be in agreement with observed X-ray spectra, thus supporting the plausibility of our nanoflare-heating scenario.

**R39** *Hot coronal loops associated with umbral brightenings*, C. E. Alissandrakis, **S. Patsourakos**, 2013, Astronomy and Astrophysics, 556, 79

Aims: We aim to investigate the association of umbral brightenings with coronal structures. Methods: We analyzed AIA/SDO high-cadence images in all bands, HMI/SDO data, soft X-ray images from SXI/GOES-15, and H$\alpha$ images from the GONG network. Results: We detected umbral brightenings that were visible in all AIA bands as well as in H$\alpha$. Moreover, we identified hot coronal loops that connected the brightenings with nearby regions of opposite magnetic polarity. These loops were initially visible in the 94 Å band, subsequently in the 335 Å band, and in one case in the 211 Å band. A differential emission measure analysis revealed plasma with an average temperature of about 6.5 $\times 10^6$ K. This behavior suggests cooling of impulsively heated loops.

**R40** *Microwave and EUV Observations of an Erupting Filament and Associated Flare and CME*, C. E. Alissandrakis, A. A. Kochanov, **S. Patsourakos**, A. T. Altyntsev, S. V. Lesovoi, N. N. Lesovoya 2013, Publications of the Astronomical Society of Japan, 65, 8

A filament eruption was observed with the Siberian Solar Radio Telescope (SSRT) on 2012 June 23, starting at around 06:40 UT, beyond the west limb. The filament could be followed in SSRT images to heights above 1 $R_\odot$, and coincided with the core of the CME, seen in LASCO C2 images. We briefly discuss the dynamics of the eruption: the top of the filament showed a smooth acceleration up to an apparent velocity of 1100 kms$^{-1}$. Images behind the limb from STEREO-A show a two-ribbon flare and the interaction of the main filament, located along the primary neutral line, with an arch-like structure, oriented in the perpendicular direction. The interaction was accompanied by strong emission and twisting motions. The microwave images show a low-temperature component, a high-temperature component associated with the interaction of the two filaments and another high-temperature component apparently associated with the top of flare loops. We computed the differential emission measure from the high-temperature AIA bands and from this the expected microwave brightness temperature; for emission associated with the top of the flare loops, the computed brightness was 35% lower than the observed value.

**R41** *Core and Wing Densities of Asymmetric Coronal Spectral Profiles: Implications for the Mass Supply of the Solar Corona*, **S. Patsourakos**, J. A. Klimchuk, P. R. Young, 2014, Astrophysical Journal, 781, 58

Recent solar spectroscopic observations have shown that coronal spectral lines can exhibit asymmetric profiles, with enhanced emissions at their blue wings. These asymmetries correspond to rapidly upflowing plasmas at speeds exceeding 50 kms$^{-1}$. Here, we perform a study of the density of the rapidly upflowing material and compare it with that of the line core that corresponds to the bulk of the plasma. For this task, we use spectroscopic observations of several active regions taken by the Extreme Ultraviolet Imaging Spectrometer of the Hinode mission. The density sensitive ratio of the Fe XIV lines at 264.78 and 274.20 Å is used to determine wing and core densities. We compute the ratio of the blue wing density to the core density and find that most values are of order unity. This is consistent with the predictions for coronal nanoflares if most of the observed coronal mass is supplied by chromospheric evaporation driven by the nanoflares. However, much larger blue wing-to-core density ratios are predicted if most of the coronal mass is supplied by

heated material ejected with type II spicules. Our measurements do not rule out a spicule origin for the blue wing emission, but they argue against spicules being a primary source of the hot plasma in the corona. We note that only about 40% of the pixels where line blends could be safely ignored have blue wing asymmetries in both Fe XIV lines. Anticipated sub-arcsecond spatial resolution spectroscopic observations in future missions could shed more light on the origin of blue, red, and mixed asymmetries.

**R42** *CME Expansion as the Driver of Metric Type II Shock Emission as Revealed by Self-consistent Analysis of High-Cadence EUV Images and Radio Spectrograms*, Kouloumvakos, A, **S. Patsourakos**, A. Hillaris, A. Vourlidas, P. Preka-Papadema, X. Moussas, C. Caroubalos, P. Tsitsipis, A. Kontogeorgos, 2014, Solar Physics, 289, 2123

On 13 June 2010, an eruptive event occurred near the solar limb. It included a small filament eruption and the onset of a relatively narrow coronal mass ejection (CME) surrounded by an extreme ultraviolet (EUV) wave front recorded by the Solar Dynamics Observatory's (SDO) Atmospheric Imaging Assembly (AIA) at high cadence. The ejection was accompanied by a GOES M1.0 soft X-ray flare and a Type-II radio burst; high-resolution dynamic spectra of the latter were obtained by the Appareil de Routine pour le Traitement et l'Enregistrement Magnetique de l'Information Spectral (ARTEMIS IV) radio spectrograph. The combined observations enabled a study of the evolution of the ejecta and the EUV wave front and its relationship with the coronal shock manifesting itself as metric Type-II burst. By introducing a novel technique, which deduces a proxy of the EUV compression ratio from AIA imaging data and compares it with the compression ratio deduced from the band-split of the Type-II metric radio burst, we are able to infer the potential source locations of the radio emission of the shock on that AIA images. Our results indicate that the expansion of the CME ejecta is the source for both EUV and radio shock emissions. Early in the CME expansion phase, the Type-II burst seems to originate in the sheath region between the EUV bubble and the EUV shock front in both radial and lateral directions. This suggests that both the nose and the flanks of the expanding bubble could have driven the shock.

**R43** *How Common Are Hot Magnetic Flux Ropes in the Low Solar Corona? A Statistical Study of EUV Observations*, A. Nindos, **S. Patsourakos**, A. Vourlidas, C. Tagikas, ApJ, 2015, 808, 117

We use data at 131, 171, and 304 Å from the Atmospheric Imaging Assembly on board the Solar Dynamics Observatory to search for hot flux ropes in 141 M-class and X-class solar flares that occurred at solar longitudes equal to or larger than 50 degrees. Half of the flares were associated with coronal mass ejections. The goal of our survey is to assess the frequency of hot flux ropes in large flares irrespective of their formation time relative to the onset of eruptions. The flux ropes were identified in 131 Å images using morphological criteria and their high temperatures were confirmed by their absence in the cooler 171 and 304 Å passbands. We found hot flux ropes in 45 of our events (32% of the flares); 11 of them were associated with confined flares while the remaining 34 were associated with eruptive flares. Therefore almost half (49%) of the eruptive events involved a hot flux rope configuration. The use of supplementary Hinode X-Ray Telescope data indicates that these percentages should be considered as lower limits of the actual rates of occurrence of hot flux ropes in large flares.

**R44** *Formation of Flux Ropes during Confined Flaring Well Before the Onset of a Major CME Event*, G. Chintzoglou **S. Patsourakos**, A. Vourlidas, ApJ, 2015, 809, 34

NOAA active region (AR) 11429 was the source of twin super-fast coronal mass ejections (CMEs). The CMEs took place within an hour from each other, with the onset of the first taking place in the beginning of 2012 March 7. This AR fulfills all the requirements for a super active region namely, Hale's law incompatibility and a $\delta$-spot magnetic configuration. One of the biggest storms of Solar Cycle 24 to date (Dst=-143 nT) was associated with one of these events. Magnetic flux ropes (MFRs) are twisted magnetic structures in the corona, best seen in 10 MK hot plasma emission and are often considered the core of erupting structures. However, their dormant existence in the solar atmosphere (i.e., prior to eruptions), is an open question. Aided by multi-wavelength observations by the Solar Dynamics Observatory (SDO) and by the Solar Terrestrial Relations Observatory (STEREO) and a nonlinear force-free model for the coronal magnetic field, our work uncovers two separate, weakly twisted magnetic flux systems which suggest the existence of pre-eruption MFRs that eventually became the seeds of the two CMEs. The MFRs could have been formed during confined (i.e., not leading to major CMEs) flaring and sub-flaring events which took place the day before the two CMEs in the host AR 1142

**R45** *A tiny event producing an interplanetary type III*, C. Alissandrakis, A. Nindos, **S. Patsourakos**, A. Kontogeorgos, P. Tsitsipis, A&A, 2015, 582, 52

Aims: We investigate the conditions under which small-scale energy release events in the low corona gave rise to strong interplanetary (IP) type III bursts. Methods: We analyzed observations of three tiny events, detected by the Nancay Radio Heliograph (NRH), two of which produced IP type III bursts. We took advantage of the NRH positioning information and of the high cadence of AIA/SDO data to identify the associated extreme-UV (EUV) emissions. We measured positions and time profiles of the metric and EUV sources. Results: We found that the EUV events that produced IP type III bursts were located near a coronal hole boundary, while the one that did not was located in a closed magnetic field region. In all three cases tiny flaring loops were involved, without any associated mass eruption. In the best observed case, the radio emission at the highest frequency (435 MHz) was displaced by 55" with respect to the small flaring loop. The metric type III emission shows a complex structure in space and in time, indicative of multiple electron beams, despite the low intensity of the events. From the combined analysis of dynamic spectra and NRH images, we derived the electron beam velocity as well as the height, ambient plasma temperature, and density at the level of formation of the 160 MHz emission. From the analysis of the differential emission measure derived from the AIA images, we found that the first evidence of energy release was at the footpoints, and this was followed by the development of flaring loops and subsequent cooling. Conclusions: Even small energy release events can accelerate enough electrons to give rise to powerful IP type III bursts. The proximity of the electron acceleration site to open magnetic field lines facilitates the escape of the electrons into the interplanetary space. The offset between the site of energy release and the metric type III location warrants further investigation.

**R46** *North-South asymmetry in the magnetic deflection of polar coronal hole jets*, G. Nistico, G. Zimbardo, S. Patsourakos, **S. Patsourakos**, V. Bothmer, V. M. Nakariakov, A&A, 2015, 583, 127

Context. Measurements of the sunspots area, of the magnetic field in the interplanetary medium, and of the heliospheric current sheet (HCS) position, reveal a possible north-south (N-S) asymmetry in the magnetic field of the Sun. This asymmetry could cause the bending of the HCS of the order of 5-10 deg in the southward direction, and it appears to be a recurrent characteristic of the Sun during the minima of solar activity. Aims: We

study the N-S asymmetry as inferred from measurements of the deflection of polar coronal hole jets when they propagate throughout the corona. Methods: Since the corona is an environment where the magnetic pressure is greater than the kinetic pressure (<<1), we can assume that the magnetic field controls the dynamics of plasma. On average, jets follow magnetic field lines during their propagation, highlighting their local direction. We measured the position angles at 1 Rs and at 2 Rs of 79 jets, based on the Solar TErrestrial RElations Observatory (STEREO) ultraviolet and white-light coronagraph observations during the solar minimum period March 2007-April 2008. The average jet deflection is studied both in the plane perpendicular to the line of sight and, for a reduced number of jets, in 3D space. The observed jet deflection is studied in terms of an axisymmetric magnetic field model comprising dipole (g1), quadrupole (g2), and esapole (g3) moments. Results: We found that the propagation of the jets is not radial, which is in agreement with the deflection due to magnetic field lines. Moreover, the amount of the deflection is different between jets over the north and those from the south pole. A comparison of jet deflections and field line tracing shows that a ratio g2/g1 $\simeq$ -0.5 for the quadrupole and a ratio g3/g1 $\simeq$ 1.6-2.0 for the esapole can describe the field. The presence of a non-negligible quadrupole moment confirms the N-S asymmetry of the solar magnetic field for the considered period. Conclusions: We find that the magnetic deflection of jets is larger in the north than in the south of the order of 25-40%, with an asymmetry that is consistent with a southward deflection of the heliospheric current sheet of the order of 10 deg, consistent with that inferred from other independent datasets and instruments.

## 0.13 Review Papers

**REV1** *High-resolution EUV imaging and spectroscopy of the corona*, **S. Patsourakos** J-C Vial, In: Solar encounter. Proceedings of the First Solar Orbiter Workshop, 14 - 18 May 2001, Puerto de la Cruz, Tenerife, Spain. Eds.: B. Battrick & H. Sawaya-Lacoste, Scientific coordinators: E. Marsch, V. Marinez Pillet, B. Fleck & R. Marsden. ESA SP-493, Noordwijk: ESA Publications Division, ISBN 92-9092-803-4, 2001, p. 13

**REV2** *SOHO Contribution to Prominence Science*, **S. Patsourakos** J-C Vial, 2002, Solar Physics, 208, 253

**REV3** *Constraining the Initiation and Early Evolution of CMEs*, 2011, **S. Patsourakos**, The Sun, the Solar Wind, and the Heliosphere, by M.P. Miralles and J. Sanchez Almeida. Proceedings of the conference held 23-30 August, 2009 in Sopron, Hungary. IAGA Special Sopron Book Series, Vol. 4. Berlin: Springer, 2011. ISBN: 978-90-481-9786-6, p.73

**REV4** *On the Nature and Genesis of EUV Waves: A Synthesis of Observations from SOHO, STEREO, SDO, and Hinode*, **S. Patsourakos**, A. Vourlidas, 2012, Solar Physics, 281,187

## 0.14 Articles in Preparation

**P1** *Solar Coronal Jets: Observations, Theory, and Modeling*, N.-E. Raouafi, **S. Patsourakos**, E. Pariat, H. Mason, A. Sterling, W. Curdt, P. Young, K. Mayer, F. Moreno-Insertis, K. Dalmasse, A. Savcheva, M. Shimojo, Y. Matsui, R. DeVore, V. Archontis, T. Török , P. Syntelis, S. K. Antiochos, E. DeLuca, 2015

## 0.15 Submitted Articles

**SUB1** *The Major Solar Eruptions of 7 March 2012: Comprehensive Sun-to-Earth Analysis* **S. Patsourakos**, M. Georgoulis, A. Vourlidas, A. Nindos, A. Kouloumvakos, O. Podlachikova,I. A. Daglis, C. Katsavrias, K. Tziotziou, K. Moraitis, C. Gontikakis, A. Anastasiadis, C. Tsironis, O.E. Malandraki, G. Balasis, M. Georgiou, I. Sandberg, C. Papadimitriou, D. L. Turner, E. Sarris, I. Voyatzis, G. Anagnostopoulos, T. Sarris, D. Sarafopoulos, G. Pavlos, A.C. Iliopoulos, E. G. Pavlos, L.P. Karakatsanis, M. Xenakis, P. Syntelis, N. Hatzigeorgiu, T. Nieves-Chinchilla, G. Chintzoglou, K. Tsinganos, L. Vlahos, ApJ, 2015

**SUB2** *Multi-viewpoint Observations of energetic proton release in a major SEP event: EUV Waves and White Light Shock SIgnatures*, A. Kouloumvakos, **S. Patsourakos**, A. Nindos, A. Vourlidas, A. Anastasiadis, A. Hillaris, I. Sandberg, ApJ, 2015

**SUB3** *Intensity Convserving Spline Interpolation (ICSI): A New Tool For Spectroscopic Analysis*, J. A. Klimchuk, Solar Physics, **S. Patsourakos**, D. Tripathi, 2015

**SUB4** *The spectroscopic imprint of the pre-eruptive configuration resulting into two major Coronal Mass Ejections*, P. Syntelis, C. Gontikakis, **S. Patsourakos**, K. Tsinganos, A&A, 2015

## 0.16 Technical Reports

**TR1** *Comparison of Algorithms for Near Real-Time Flare Location with Solar Truth*, S. P. Plunkett, J.S. Newmark, D. R. McMullin, **S. Patsourakos**, V. Kunkel, 2009, report prepared for NOAA/SWPC

## 0.17 Publications in Conference Proceedings

**PR1** Simulated White-Light Images of Coronal Structures as obtained by the CORI Imager On-Board a Solar Probe, S. Patsourakos J.-C Vial , 1997, Robotic Exploration Close to the Sun: Scientific Basis. Marlboro, MA, April 1996. Edited by Shadia Rifai Habbal. AIP Conference Proceedings, vol. 385. American Institute of Physics, Woodbury, NY, 1997., p.129

**PR2** Low Transition-Region Characteristics of Equatorial Coronal Holes, S. Patsourakos et al. , 1997, Fifth SOHO Workshop: The Corona and Solar Wind Near Minimum Activity. held at Institute of Theoretical Astrophysics. University of Oslo, Norway, 17-20 June, 1997. Edited by A. Wilson, European Space Agency, 1997., p.577

**PR3** Coordinated Observations Between SOHO/SUMER and Ground During the 1998 Total Eclipse: Non-thermal Line Broadenings and Electron Densities in a Polar Coronal Hole, S. Patsourakos, J-C Vial , J-R Gabryl, S. Koutchmy U. Schuhle, Solar Wind Nine, Proceedings of the Ninth International Solar Wind Conference, Nantucket, MA, October 1998. Edited by Shaddia Rifai Habbal, Ruth Esser, Joseph V. Hollweg, and Philip A. Isenberg. AIP Conference Proceedings, Vol. 471, 1999., p.285

**PR4** The Coarse Versus the Fine Structure of the Quiet-Sun Chromospheric and Transition Region Network, S. Patsourakos, J-C Vial, A.-H. Gabriel N. Bellamine, 8th SOHO Workshop: Plasma Dynamics and Diagnostics in the Solar Transition Region and Corona. Proceedings of the Conference held 22-25 June 1999 in CAP 15, 1-13 Quai de Grenelle, 75015 Paris, France. Sponsored by ESA, NASA, C.N.R.S.-I.N.S.U., Euroconferences, Institut d'Astrophysique Spatiale, Matra Marconi Space, SCOSTEP, University Paris XI. ESA Special Publications 446. Edited by J.-C. Vial and B. Kaldeich-Sch?mann., p.537

**PR5** Constraints on Ion Temperatures at the Coronal Base of an Interplume Region from Coordinated Eclipse and SOHO Observations, S. Patsourakos J-C Vial, International Meeting on Eclipses and the Solar Corona, Institut dB'AAstrophysique de Paris, April 14 15, 2000

**PR6** High-resolution EUV imaging and spectroscopy of the corona, S. Patsourakos J-C Vial, In: Solar encounter. Proceedings of the First Solar Orbiter Workshop, 14 - 18 May 2001, Puerto de la Cruz, Tenerife, Spain. Eds.: B. Battrick H. Sawaya-Lacoste, Scientific coordinators: E. Marsch, V. Marinez Pillet, B. Fleck R. Marsden. ESA SP-493, Noordwijk: ESA Publications Division, ISBN 92-9092-803-4, 2001, p. 13 ? 21

**PR7** Searching the source regions of the fast solar wind in polar coronal holes and the potential of the Solar Orbiter, S. Patsourakos J-C Vial, In: Solar encounter. Proceedings of the First Solar Orbiter Workshop, 14 - 18 May 2001, Puerto de la Cruz, Tenerife, Spain. Eds.: B. Battrick H. Sawaya-Lacoste, Scientific coordinators: E. Marsch, V. Marinez Pillet, B. Fleck R. Marsden. ESA SP-493, Noordwijk: ESA Publications Division, ISBN 92-9092-803-4, 2001, p. 321 ? 325

**PR8** What are the Origins of Quiescent Coronal Soft X-Rays? Foley, C. R.;Culhane, J. L.; Patsourakos, S.; Yurow, R.; Moroney, C.; Mackay, D Multi-Wavelength Observations of Coronal Structure and Dynamics Yohkoh 10th Anniversary Meeting. Proceedings of the conference held September 17-20, 2001, at King Kamehameha's Kona Beach Hotel in Kailua-Kona, Hawaii, USA. Edited by P.C.H. Martens and D. Cauffman. Published by Elsevier Science on behalf of COSPAR in the COSPAR Colloquia Series, 2002., 341

**PR9** The polar coronal holes and the fast solar wind: Some recent results, S. Patsourakos, S.-R. Habbal, J.-C. Vial, and Y. Q. Hu, Joint SOHO/ACE workshop "Solar and Galactic Composition". Edited by Robert F. Wimmer-Schweingruber. Publisher: American Institute of Physics Conference proceedings vol. 598 location: Bern, Switzerland, March 6 - 9, 2001., p.299

**PR10** Fuzzy hot post-flare loops versus cool post-flare loops, S. Patsourakos, S. K Antiochos J. A. Klimchuk, SOLMAG 2002. Proceedings of the Magnetic Coupling of the Solar Atmosphere Euroconference and IAU Colloquium 188, 11 - 15 June 2002, Santorini, Greece. Ed. H. Sawaya-Lacoste. ESA SP-505. Noordwijk, Netherlands: ESA Publications Division, ISBN 92-9092-815-8, 2002, p. 207 ? 210

**PR11** The Effect of the Spatial Distribution of Nanoflare Heating on Loop Observables, S. Patsourakos J. A. Klimchuk, 2004, Proceedings of the SOHO 15 Workshop - Coronal Heating. 6-9 September 2004, St. Andrews, Scotland, UK (ESA SP-575). Editors: R.W. Walsh, J. Ireland, D. Danesy, B. Fleck. Paris: European Space Agency, 2004., p.297

**PR12** Coronal Loop Heating by Nanoflares: Some Observational Implications, S. Patsourakos J. A. Klimchuk, Proceedings of the 6th Hellenic Society Conference, 15-17 September 2003, Penteli, Athens, Greece, pp 35-40

**PR13** Impulsive Coronal Heating at Sub-arcsecond Scales: What is the Best Diagnostic? , S. Patsourakos J. A. Klimchuk, 2006, Proceedings of the Second Solar Orbiter Workshop, ESA-SP 641

## 0.18 Citations

Scopus and NASA's ADS

## 0.19 Announcements in Conferences

[**T**]: talk [**P**]: poster

**C1** Simulated White-Light Images of Coronal Structures as obtained by the CORI Imager On-Board a Solar Probe, S. Patsourakos J.-C Vial , 1997, Robotic Exploration Close to the Sun: Scientific Basis. Marlboro, MA, April 1996 [**T**]

**C2** Low Transition-Region Characteristics of Equatorial Coronal Holes, S. Patsourakos et al., 1997, Fifth SOHO Workshop: The Corona and Solar Wind Near Minimum Activity. held at Institute of Theoretical Astrophysics. University of Oslo, Norway, 17-20 June 1997 [**T**]

**C3** Coordinated Observations Between SOHO/SUMER and Ground During the 1998 Total Eclipse: Non-thermal Line Broadenings and Electron Densities in a Polar Coronal Hole, S. Patsourakos, J-C Vial, J-R Gabryl, S. Koutchmy U. Schuhle, Solar Wind Nine, Ninth International Solar Wind Conference, Nantucket, MA, October 1998 [**P**]

**C4** The Coarse Versus the Fine Structure of the Quiet-Sun Chromospheric and Transition Region Network, S. Patsourakos, J-C Vial, A.-H. Gabriel N. Bellamine, 8th SOHO Workshop: Plasma Dynamics and Diagnostics in the Solar Transition Region and Corona.22-25 June 1999 in CAP 15, 1-13 Quai de Grenelle, 75015 Paris, France [**T**]

**C5** SXR flashes and jetlets in Polar Coronal Holes, S. Patsourakos S. Koutchmy, EGS XXV General Assembly, Nice, France, April 2000 [**T**]

**C6** High-resolution EUV imaging and spectroscopy of the corona, S. Patsourakos J-C Vial, In: Solar encounter. Proceedings of the First Solar Orbiter Workshop, 14 - 18 May 2001, Puerto de la Cruz, Tenerife, Spain [**T**]

**C7** Searching the source regions of the fast solar wind in polar coronal holes and the potential of the Solar Orbiter, S. Patsourakos J-C Vial, In: Solar encounter. Proceedings of the First Solar Orbiter Workshop, 14 - 18 May 2001, Puerto de la Cruz, Tenerife, Spain [**P**]

**C8** Some Recent Results on the Source Regions of the Fast Solar Wind, S. Patsourakos J-C Vial, RAS meeting, 2000, London, UK [**T**]

**C9** Hot versus Cool Coronal Loops, S. Patsourakos, S. K. Antiochos J. A. Klimchuk, 2002, American Astronomical Society, 200th AAS Meeting [**P**]

**C10** Fuzzy hot post-flare loops versus cool post-flare loops, S. Patsourakos, S. K Antiochos J. A. Klimchuk, SOLMAG 2002. Proceedings of the Magnetic Coupling of the Solar Atmosphere Euro conference and IAU Colloquium 188, 11 - 15 June 2002, Santorini, Greece. [**T**]

**C11** Cross-field Properties of Coronal Loops from TRACE triple-filter observations, S. Patsourakos J. A. Klimchuk, 2002, 1st Coronal Loop Workshop, Orsay, France [**T**]

**C12** Bright Knots in EUV Post-flare Loops: TRACE Observations and 1D Hydrodynamic Modeling, S. Patsourakos, S. K. Antiochos J. A. Klimchuk, American Geophysical Union, Fall Meeting 2002 [**T**]

**C13** Can Steady-state Mass Flows Explain the Non-hydrostatic Cool EUV Coronal Loops In Active Regions? S. Patsourakos J. A. Klimchuk, 2003,American Astronomical Society, SPD meeting [**T**]

**C14** Coronal Loop Heating by Nanoflares: Some Observational Implications, S. Patsourakos J. A. Klimchuk, 6th Hellenic Society Conference, 15-17 September 2003, Penteli, Athens, Greece [**T**]

**C15** Coronal Loop Heating by High-frequency ion-cyclotron waves, S. Patsourakos, J. A. Klimchuk, The 13th SOHO Workshop B•Waves, Oscillations and Small-scale Transient Events in the Solar Atmosphere: A Joint View of SOHO and TRACEB'A, Palma de Mallorca, Spain 2003 [**T**]

**C16** Ion effective Temperatures in Polar Coronal Holes: Observations and ion-cyclotron resonant Heating, S. Patsourakos, S. R. Habbal, Coronal Wave Workshop, GSFC, USA, 2003 [**T**]

**C17** Bright EUV Knots in Solar Flare Loops: Constraints on Coronal Heating, S. Patsourakos, S. K. Antiochos J. A. Klimchuk, 2004, American Astronomical Society, SPD meeting [**T**]

**C18** The Effect of the Spatial Distribution of Nanoflare Heating on Loop Observables, S. Patsourakos J. A. Klimchuk, 2004, SOHO 15 Workshop - Coronal Heating. 6-9 September 2004, St. Andrews, Scotland, UK [**T**]

**C19** Non-thermal Velocities and the Nanoflare Model, S. Patsourakos, J. A. Klimchuk,2nd Solar Coronal Loop Workshop and SOLAR-B discussion, Palermo, Italy, 2004 [**T**]

**C20** Coronal Loop Heating by Nanoflares: Non-thermal Velocities, S. Patsourakos J. A. Klimchuk, 2005, American Geophysical Union, Spring Meeting 2005 [**P**]

**C21** Coronal Loop Heating by Nanoflares: The Impact of the Field-aligned Distribution of the Heating on Loop Observations, S. Patsourakos J. A. Klimchuk, 2005, American Geophysical Union, Spring Meeting 2005 [**P**]

**C22** Spectroscopic Diagnostics of Nanoflare Heating in Coronal Loops, S. Patsourakos J. A. Klimchuk, 2005, 7th Hellenic Society Conference, 2005, Kefallonia [**T**]

**C23** Testing Nanoflare Heating in Coronal Loops With Observations From the Extreme Ultraviolet Imaging Spectrometer On-board the SOLAR-B Mission, S. Patsourakos J. A. Klimchuk, 2006, American Astronomical Society, Solar Physics Division 2006 meeting, 2006 [**P**]

**C24** Impulsive Coronal Heating At Sub- Arcsecond Scales: What Is The Best Diagnostic?, S. Patsourakos, J. A. Klimchuk, 2006, Second Solar Orbiter Workshop, Athens, Greece, 2006 [**T**]

**C25** Cool Loops in the Quiet Sun Network: VAULT Observations and the Promise of Solar Orbiter, S. Patsourakos, P. Goutebroze A. Vourlidas, 2006, Second Solar Orbiter Workshop, Athens, Greece, 2006 [**P**]

**C26** Modeling Active Regions with Steady and Impulsive Heating S. Patsourakos, J. A. Klimchuk, 2007 American Astronomical Society Meeting 210 [**P**]

**C27** The Cross-field Thermal Structure of Coronal Loops From Triple-filter TRACE Observations, S. Patsourakos, J. A. Klimchuk, 2007, 3rd Coronal Loops Workshop, Santorini, Greece [**T**]

**C28** Towards a Better Understanding of CME Onsets with SECCHI on STEREO, S. Patsourakos, A. Vourlidas, 2007, American Geophysical Union, Fall Meeting 2007 [**P**]

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**C30** The SECCHI View of EIT Waves, S. Patsourakos, A. Vourlidas, G. Stenborg, 2008, EGU General Assembly 2008, Vienna, Austria, 13 ? 18 April 2008 [**T**]

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**C32** Hot Spectral Emissions in Quiescent Active Regions and Nanoflare Heating, Patsourakos, S.; Klimchuk, J. A., 2008, American Geophysical Union, Spring Meeting 2008, [**T**]

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**C34** STEREO Observations of EUV Waves, S. Patsourakos, 2008 Solar, Heliospheric and Interplanetary Envirnonmment (SHINE) Workshop, June 2008, Zermatt, Utah, USA. [**T**]

**C35** STEREO Observations of EUV Waves, S. Patsourakos, A. Vourlidas, G. Stenborg, A. Thernisien and Y. M. Wang, 2008 8th SECCHI Consortium Meeting, 22-24 Oct 2008, NRL, Washington-DC, USA, [**T**]

**C36** STEREO Observations of a post-CME Current Sheet, Patsourakos, S.; Vourlidas, A.; Stenborg, G. American Geophysical Union, Fall Meeting 2008 [**T**]

**C37** Constraints on impulsively accelerated CMEs from STEREO observations, S. Patsourakos, STEREO 3 / SOHO 22, Apr 27 - May 1, 2009, Dorset, England [**T**]

**C38** Spectroscopic Observations of Hot Lines Constraining Coronal Heating in Solar Active Regions, 2009, 2009 AAS/Solar Physics Division Meeting [**P**]

**C39** Quadrature STEREO Observations Determine the Nature of EUV Waves, Kliem, Bernhard; Patsourakos, S.; Vourlidas, A.; Ontiveros, V., 2009, 2009 AAS/Solar Physics Division Meeting [**T**]

**C40** CONSTRAINTS ON CME INITIATION AND EARLY EVOLUTION FROM SECCHI ON STEREO, S. Patsourakos, 2009, 2009 General Assembly of IAGA, Sopron, Hungary [**T**]

**C41** STEREO Observations Determine the Nature of EUV Waves, S. Patsourakos, A. Vourlidas, 2009, The 9th Hellenic Astronomical Conference, Athens [**T**]

**C42** The Genesis of an Impulsive CME observed by AIA on SDO, Patsourakos, S.; Vourlidas, A.; Stenborg, G., 2010, American Geophysical Union, Fall Meeting 2010, [**T**]

**C43** The Role of Chromospheric Evaporation into Coronal Mass Supply, S. Patsourakos, 2011, The Fifth Coronal Loops Workshop, Palma (Malliorca), [**T**]

**C44** EUV Waves: The Evolving View from SOHO to Hinode, STEREO and SDO, 2011 Stereo-4/SDO-2/SOHO-25 Workshop, Kiel Germany [**T**]

**C45** Constraining a Model for EUV Wave Formation with SDO and STEREO Quadrature Observations, Patsourakos, S.; Vourlidas, A.; Olmedo, O., 2011, 10th Hellenic Astronomical Conference, Ioannina, [**T**]

**C46** Signatures of Impulsive Coronal Heating in Warm and Hot Spectral Lines, S. Patsourakos, J. A. Klimchuck, P. R. Young, 13th European Solar Physics Meeting Rhodes, Greece, 12-16 September 2011 [**T**]

**C47** Implications for the Mass Supply of the Solar Corona from the Density of Asymmetric Coronal Spectral Profiles, S. Patsourakos, J. A. Klimchuck, P. R. Young, 26th IUGG General Assembly, Prague, Czeck Republic, June 22-July 2 2015 [**P**]

**C48** Parametric Study of a Helicity-based Method to Infer the Near-Sun Magnetic Field of Coronal Mass Ejections, S. Patsourakos, M. K. Georgoulis, 16th IUGG General Assembly, Prague, Czeck Republic, June 22-July 2 2015 [**P**]

**C49** A Helicity-based Method to Infer the Near-Sun Magnetic Field of Coronal Mass Ejections: Parametric Study and Comparison with Observations at 1 AU, S. Patsourakos, M. K. Georgoulis, 12th Hellenic Astronomical Conference,Thessaloniki, Greece, 28 June -2 July 2015 [**T**]

## 0.20 Invited Talks

**INV1** High-resolution EUV imaging and spectroscopy of the corona, **S. Patsourakos** and J-C Vial, In: Solar encounter. The First Solar Orbiter Workshop, 14 - 18 May 2001, Puerto de la Cruz, Tenerife, Spain.

**INV2** Constraining the Initiation and Early Evolution of CME, **S. Patsourakos**, in the 2009 IAGA conference held 23-30 August, 2009 in Sopron, Hungary.

**INV3** EUV Waves, **S. Patsourakos**, in the The Sun 360: Stereo-4/SDO-2/SOHO-25 Workshop, July 25 - 29, 2011, Christian-Albrechts-Universitat, Kiel, Germany

**INV4** The Role of Chromospheric Evaporation into the Coronal Mass Supply, **S. Patsourakos**, in the The Fifth Coronal Loops Workshop. June 29 - July 2, 2011. Palma de Mallorca, Spain.

**INV5** Recent Developments in the Study of the Early Stages of Coronal Mass Ejections, **S. Patsourakos**, IAGA 2013 $12^{th}$ Scientific Assembly, 26-31 August 2013, Merida, Mexico

**INV6** Sun-to-Earth Analysis of a Major Geoeffective Solar Eruption with the Framework of the Hellenic National Space Weather Network, **S. Patsourakos**, L. Vlahos, M. Georgoulis, K. Tziotziou, A. Nindos, O. Podladchikova, A. Vourlidas, A. Anastasiadis, I. Sanberg, K. Tsiganos, I. Daglis, A. Hillaris, P. Preka-Papadema, M. Sarris, T. Sarris, The $11^{th}$ Hellenic Astronomical Conference, 8-12 September 2013, Athens, Greece

**INV7** Sun-to-Earth Analysis of a Major Solar Eruption, **S. Patsourakos** and the HNSWN, $40^{th}$ COSPAR Scientific Assembly. Held 2-10 August 2014, in Moscow, Russia

**INV8** Observations of CMEs-ICMEs: Results from Current Space Missions and Expectations from Future Instrumentation,**S. Patsourakos**, $40^{th}$ COSPAR Scientific Assembly. Held 2-10 August 2014, in Moscow, Russia

**INV9** Connecting upstream transient phenomena and their effects on geospace: the major solar eruptions of 7 March 2012, **S. Patsourakos** and the Hellenic National Space Weather Research Network, Geospace revisited: a CLUSTER/MAARBLE/Van Allen Probes Conference, 15-20 September 2014, Rhodes, Greece

**INV10** EUV Coronal Waves: Atmospheric and Heliospheric Connections and Energetics, **S. Patsourakos**, 2015 AGU Fall, San Francisco, USA, 14-18 December 2015.

## 0.21 Seminars

Departments of Physics of Universities of Athens, Thessaloniki, Ioannina

Institute for Astronomy, Astrophysics, Space Applications & Remote Sensing, National Observatory of Athens

Research Center for Astronomy and Applied Mathematics of the Academy of Athens

Mullard Space Science Laboratory, University College of London

The Johns Hopkins University Applied Physics Laboratory

Goddard Space Flight Center, NASA

Naval Research Lab

School of Physics, Astronomy, and Computational Sciences, George Mason University

## 0.22 Participation in Research Programmes and Teams

**1997-2000:** E.U. fellow "Investigation of Coronal Heating and Wind Acceleration in Solar Coronal Holes" under the TMR Programme

**1997-2000:** Coordinator Observing Programme 40 "Transition Region Network Thickness" of the ESA/NASA SOHO satellite including various instruments of SOHO (SUMER,CDS,MDI, EIT)

**1997-2001:** Member of the scientific planning teams of the CDS and SUMER instruments of the SOHO ESA/NASA mission

**1998** Co-ordinator of campaign of space SOHO/SUMER and ground observations during the total solar eclipse of the 26th February 1998.

**2001-2009:** Co-investigator in 3 research grants of NASA

**2003-** Scientific collaborator of the rocket experiments VAULT and VERIS

**2007** Coordinator of the Hinode Satellite Observing Plan 0047, "SUMER campain-Moss Observation" involving observations from 3 satellites: SOHO (SUMER), Hinode (EIS, XRT, SOT) and STEREO (SECCHI)

**2007-2008** Member of an International Study Team on (The Role of Spectroscopy and Imaging Data in Understanding Coronal Heating) of the International SPace Science Institute:ISSI

**2008-** Co-investigator of the SECCHI instrument of the STEREO mission of NASA

**2009-** Scientific collaborator of the ASPIICS instrument of the PROBA III mission of ESA

**2009-** Co-investigator of the LEMUR: Large European Module for solar Ultraviolet Research. European contribution to JAXA's Solar-C mission

**2010-2011** Guest Investigator of the PROBA II mission of ESA.

**2010-2014** E.U. fellow Solar Eruptive Phenomena: Understanding their Initial Stages and Determine their Arrival Times to Earth `http://users.uoi.gr/spatsour/sep/sep.html`

**2012-2015** Co-investigator of the Hellenic Space Weather Network under the national and E.U. action THALIS

**2012-2015** Coordinator of the study team of a major solar eruption from the Sun to the Earth in the frame of the Hellenic Space Weather Network

**2013-2014** Member of an International Study Team on the (Understanding Solar Jets and their Role in Atmospheric Structure and Dynamics) of the International Space Science Institute:ISSI

**2014-** Co-investigator of the Heliospheric Imager of the Solar Orbiter ESA/NASA mission

**2014-** Leader of WG5 (Bs Challenge Group) of Variability of the Sun and Its Terrestrial Impact (VarSITI) International Study of Earth-affecting Solar Transients International initiative, http://solar.gmu.edu/heliophysics/index.php/WorkingGroup$_5$

**2015-** Member of the scientific team of the ARTEMIS radiospectograph

**2015-** Co-investigator of the MASC (Magnetic Activity of the Solar Corona) proposal to ESA/CAS

**2015-** Coordinator of the International Study Team on the (Decoding the Pre-Eruptive Magnetic Configurations of Coronal Mass Ejections) of the International Space Science Institute:ISSI

## 0.23 Refereeing Activities

Referee for Solar Physics, Astronomy and Astrophysics, Astrophysical Journal and Nonlinear Processes in Geophysics

Reviewer of NASA, NSF, Agence Nationale de la Research and Czech Science Foundation proposals

## 0.24 Participation in Committees

Member of the Education and Public Outreach Committee of the Solar Physics Division (SPD) of the American Astronomical Society (AAS) (2007-2009).

Member of the following committees of the Department of Physics of the University of Ioannina: Seminars (2009-), buildings and safety (2011-2012), Program of studies (2013-), translation (2012-).

Delegate of the Department of Physics in the Committee of acceptance of new hardware, instruments etc of the University of Ioannina (2013-2014).

Elected member of the Coronal Loops Workshops Steering Committee (2012-2014).

Elected auditor of the Hellenic Astronomical Society (2012-2014, 2014-2016).

Member of the selection commmittee of the Sunanda and Santimay Basu Early Career Award in Sun-Earth Systems Science of AGU (2014-).

Chair of Division IV Solar Wind and Interplanetary Field of IAGA (2015-2019)

## 0.25 Conference Organisation

Member of the Local Organizing Committee of the 2nd Solar Orbiter Workshop, Oct 2006, 16-20 Oct 2006, Athens, Greece

Chair of the Scientific and of the Local Organizing Committees of the Coronal Loops Workshop, 18-21 June 2007, Santorini, Greece

Chair of the Local Organizing Committee of the 10th Hellenic Astronomical Conference, 5-8 September 2011, Ioannina, Greece

Member of the Local Organizing Committee of the ESPM-13: 13th European Solar Physics Meeting, 12-16 Sep 2011, Rhodes, Greece

SOC member of the 1st Summer School of the Hellenic Astronomical Society, Athens, 1-5 September 2014

Organiser of the Mini-Workshop: Sun-to-Earth Analysis of an Extreme Space Weather Event, Department of Physics, University of Ioannina, Greece 9 - 10 January 2014

Convener of Session A28 New advances in Solar and Interplanetary Physics (Div. IV) of IAGA during the 2015 IUGG meeting

Co-chair of the scientific and local organizing committees of the Conference: Multi-wavelength Studies of the Solar Atmosphere: Celebrating the Career of Costas Alissandrakis, Ioannina, Greece, 21-24 September 2015.

Co-convener of session "Insights for Early Predictions of Magnetic and Dynamic Properties of Interplanetary Coronal Mass Ejections using Observations, Theory and Modeling" during the EGU 2016 General Assembly, Vienna, Austria, 17-22 April 2016.

Co-convener of session "Solar-Terrestrial Coupling and Space Weather: State-of-the-Art and Future Prospects" of the 2016 EWASS, Athens Greece, 4 July - 8 July 2016.

Member of the scientific organizing committee of session D2.1: Solar Transients: from Solar Origin to Earth Impact and the Outer Heliosphere of the 2016 COSPAR Scientific Assembly, Istanbul, Turkey, 30 July - 7 August 2016.

## 0.26 Media and Internet Coverage of Research Activities

- Press Conference in the 2008 Joint Assembly of American Geophysical Society (AGU), 27-30 May 2008, Ft Lauderdale, Florida, USA
  `http://www.agu.org/news/press/pr_archives/2008/2008-18.html`- Results covered by "Sky and Telescope" , "National Geographic"
  `http://news.nationalgeographic.com/news/2008/06/080603-solar-tornadoes.html`
- NASA headline
  `http://science.nasa.gov/headlines/y2009/24nov_solartsunami.htm`
- KATHIMERINI newspaper article (in greek)
  `http://news.kathimerini.gr/4dcgi/_w_articles_ell_3_08/06/2008_272930`
- NASA
  http://www.nasa.gov/mission_pages/sdo/news/flux−ropes.html
- UK Solar Physics Newsletter
  http://www.uksolphys.org/uksp-nugget/20-rapid-cavity-formation-and-expansion-in-cmes/
- Royal Astronomical Society
  https://www.ras.org.uk/news-and-press/2671-does-the-solar-magnetic-field-show-a-north-south-divide