1 Abstract

The remote sensing of solar and stellar plasmas requires the analysis of weak, often variable signals that must be interpreted in the context of complex atomic processes in order to derive insights into the underlying physics. We propose a cross-disciplinary ISSI team composed of experts in atomic physics, statistical inference, and solar and stellar data analysis that will probe the limits of our ability to understand physical processes in such environments, through the systematic study of uncertainty in analyzing and interpreting remote sensing observations.

Over the past several decades atomic data for almost all ions of astrophysical importance have been computed and accumulated into publicly available databases, such as AtomDB and CHIANTI. The problem of assessing the uncertainties in these calculations and incorporating this information into the analysis of observations has now come to the fore. At the center of our proposal is an integrated approach to the treatment of uncertainty in atomic physics calculations. Recent work on the AtomDB atomic physics database project has provided uncertainties for many of the important parameters, such as collision strengths and recombination rates, needed for calculating ionization fractions and level populations. Rigorous methods for propagating these uncertainties, however, have yet to be developed and widely applied.

Another key objective of this team will be the adoption of a framework that treats the uncertainties in the atomic data and the observational data in a holistic manner. Therefore we will adopt a Bayesian approach for all aspects of the analysis and interpretation the observations. Every aspect of data analysis involves assumptions and the Bayesian approach will allow for a rigorous treatment of the uncertainties associated with these assumptions. One of the primary goals of the team will be the application of the techniques we develop to determining the thermal structure of solar and astrophysical sources. We will complete the end-to-end analysis of several datasets from observatories such as *Chandra*, *XMM Newton*, *Hinode*, *SDO*, and *SoHO* that includes uncertainties in the intensity measurements, the atomic physics calculations, and, ultimately, the inferred thermal structure of the plasma being observed.

The multidisciplinary and exploratory aspects of this work make it ideal for an international ISSI team. Individual researchers are currently working on many aspects of this problem. Their efforts, however, are not coordinated and the sharing of information and ideas has been slow. Forming an ISSI team that brings together experts from different disciplines will accelerate the progress on this important topic. The results from this working group will have a broad impact in the astrophysical community.

2 Scientific Motivation

To illustrate the challenge of interpreting solar and stellar observations we briefly review some recent work on computing the temperature structure of solar active regions. Such measurements hold potential clues to how the solar corona is heated to high temperatures, but it is unclear how to reliably interpret the observations. This is only one of a broad range of problems that would greatly benefit from the coordinated effort among atomic physicists, statisticians, and astrophysicists that we are proposing.

Perhaps the most widely studied theory for describing how energy stored in the Sun's magnetic field is converted into thermal energy is the Parker nanoflare model (e.g., Parker, 1972,

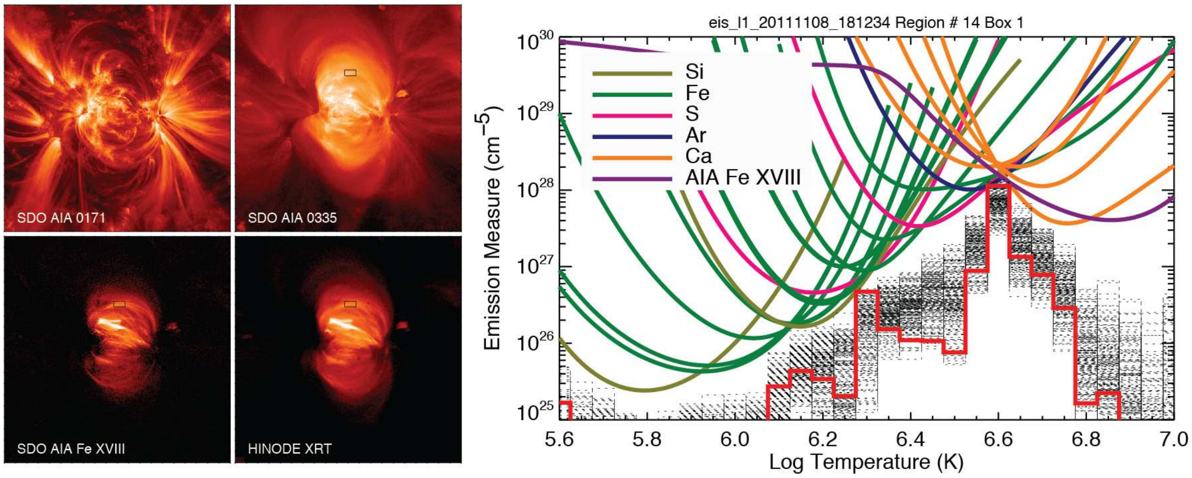

Figure 1: An example of an active region temperature measurement using *Hinode* and *SDO* (Warren et al., 2012). The sharply peaked temperature distribution is a challenge to nanoflare heating models, but how much do the uncertainties in the observations, the atomic data, and the inversion limit our ability to constrain the coronal heating problem? Nearly simultaneous spectroscopic observations from EIS and AIA Fe XVIII 94 Å have been used to compute the differential emission measure distribution (red curve in the right panel) for a small region of interest (the box in the image data). An estimate of the uncertainty in the DEM has been computed using the statistical errors in the line intensity measurements (the black curves), but uncertainties in the atomic parameters have not been included.

1983). In this model turbulent photospheric motions drive the twisting and braiding of the magnetic field, which leads to the release of energy on small spatial scales as the accumulated topological complexity is dissipated by magnetic reconnection. Since these heating events are likely to occur on very small spatial scales relative to the spatial resolution of the observations, simulations of nanoflare heating have assumed that observable structures are composed of many unresolved loops that are in various stages of heating and cooling. Thus a broad distribution of temperatures was anticipated (e.g., Cargill, 1994; Klimchuk & Cargill, 2001; Patsourakos & Klimchuk, 2006; Guarrasi et al., 2010; Mulu-Moore et al., 2011; Bradshaw et al., 2012).

So far, unambiguous observational signatures of nanoflares have failed to materialize. Combined observations from *Hinode* and *SDO*, for example, have the required sensitivity to measure the distribution of temperatures in an active region (e.g., Del Zanna, 2013; Warren et al., 2012), but the distributions are generally much narrower than expected. An example calculation is shown in Figure 1. Here intensities from *Hinode*/EIS and *SDO*/AIA have been combined to infer the differential emission measure distribution (DEM) using the usual expression

$$I_\lambda = \frac{1}{4\pi}\int \epsilon_\lambda(n_e, T_e)\xi(T_e)\,dT_e, \tag{1}$$

where $\epsilon_\lambda(n_e, T_e)$ is the emissivity and the function $\xi(T_e) \equiv n_e^2\,ds/dT_e$ is the differential emission measure. The emissivity contains information on the atomic transition that produces the observed emission

$$\epsilon_\lambda(n_e, T_e) \equiv \frac{hc}{\lambda}A_{ul}\frac{n_u}{n_{ion}}\frac{n_{ion}}{n_{el}}\frac{n_{el}}{n_H}\frac{n_H}{n_e}\frac{1}{n_e}, \tag{2}$$

where A_{ul} is the rate at which the upper level of the atomic transition is depopulated by spontaneous decay, n_u/n_{ion} is fraction of ions in the upper level (the level population), n_{ion}/n_{el} is the fraction of ions in a given ionization state (the ionization fraction), and n_{el}/n_H is the abundance of the element relative to H. For this example the emissivities have been computed using the CHIANTI atomic database (e.g., Dere et al., 1997; Landi et al., 2012). The inversion of the intensities was performed using Monte Carlo Markov Chain (MCMC) based emission measure reconstruction algorithm (Kashyap & Drake, 1998, 2000) distributed with the `PINTofALE` spectral analysis package.

The DEM is calculated assuming that atomic parameters used to compute the emissivity are well known. In truth, the collision and de-excitation rates that determine the level populations, the ionization and recombination rates that determine the ionization fractions, and the elemental abundances are all uncertain. Unfortunately, the systematic evaluation of the errors in the atomic parameters has yet to be completed so this question cannot be considered rigorously at the moment. Initial work has suggested that these uncertainties may strongly limit our ability to infer the properties of solar plasma with remote sensing observations (Guennou et al., 2013; Landi et al., 2012). Of course, the results from current atomic databases are generally compared against available observations and often yield differences closer to 10–20% (see, for example, series of benchmark papers on an ion-by-ion basis starting from Del Zanna et al. 2004).

Another complication in the analysis of data such as these is that emission at the limit of detection plays an important role in determining the DEM over the full range of temperatures of interest. For example, Del Zanna & Mason (2014) recently reanalysed soft X-ray spectra from the Solar Maximum Mission (SMM) to investigate the DEM at temperatures above 3 MK. These data, however, could only provide an upper bound on the Fe XVIII 14.20 Å line. Their analysis indicated very little emission at the highest temperatures. Similarly, the thickest *Hinode*/XRT filters often show very little signal in active region observations. The optimal way to include weak emission as a constraint in determining the temperature structure is unclear.

Finally, the calculation of the DEM from Equation 1 involves solving an ill-posed integral equation. Many authors (e.g., Craig & Brown, 1976; Judge et al., 1997; Testa et al., 2012) have argued that any "solution" is largely a reflection of the assumptions made to regularize the inversion.

3 Plans and Goals

Atomic Physics The AtomDB team (Foster et al., 2012; Smith et al., 2001) has begun a long-term effort to include practical errors on the spectral models we provide. Figure 2 shows some of the latest results on the G ratio, a temperature diagnostic that uses helium-like ion line ratios. The inset to Figure 2 shows an early effort, where the rate of each process (excitation, recombination, etc) was assumed to have a fixed uncertainty, ignoring correlations between processes. The final result, unsurprisingly, was of little use as the errors simply propagated into the line ratio. The current approach starts with multiple calculations of the underlying atomic models, varying the inputs to these models within plausible ranges to develop many different possible sets of rates. Each set of rates, however, is used as a group to maintain the built-in correlations. As shown in Figure 2, this method returns uncertainties that vary with temperature, tending toward zero at high temperature as the relevant processes tend towards the analytic Bethe limit.

While computationally intensive and incomplete — the definition of "plausible" must be made concrete — the approach is promising. Incorporating these uncertainties into a practical analysis tool, however, will require significant coordination and consideration of the difficulties within the context of a multidisciplinary team.

Bayesian Inference The advent of powerful but inexpensive computer resources has brought a renewed interested in applying Bayesian techniques to the analysis of large data sets. Bayesian inference represents a "super-set" of traditional least-squares analysis that can account for both prior information and complex noise models. This framework provides a rigorous way to compare models. It also makes explicit all of the available information and assumptions and provides the correct propagation of uncertainty from observations to inferred parameters.

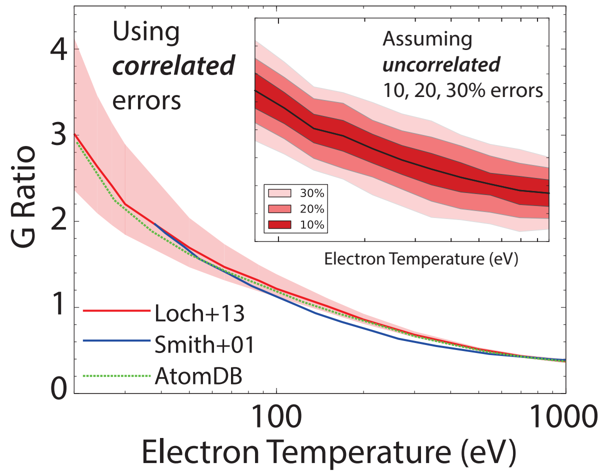

Figure 2: A comparison of the uncertainty in the G-ratio for measuring temperatures from He-like line ratios using two methods. One method (inset) assumes that the emissivites are uncorrelated, while the other (main figure) considers different realizations of the level populations and yields a more realistic range of temperatures for a given ratio.

For problems of parameter estimation, such as fitting a Gaussian to a spectral line profile, the methods for applying Bayes' theorem are well established. However, the analysis of solar and stellar spectra requires interpreting the observations using atomic physics parameters that are are themselves uncertain, affected by measurement error, are theoretical estimates that may have numerical or systematic biases, or are entirely missing. This adds an extra layer of complexity to the application of Bayesian techniques to problems such as the temperature calculation discussed in the previous section. Lee, Kashyap, van Dyk, et al. (2011) have developed a hybrid approach for analyzing observations in the presence of calibration uncertainty, which has very similar properties to the work that we are proposing. Using this approach we would alternate between sampling from a small number of realizations of the atomic data parameters and updating the distribution of model parameters using MCMC. The results of Lee et al. (2011) suggest that only a modest number of samples of the atomic physics would be required (≈ 20). Lee et al. (2011) also discussed the method of "multiple imputation" where the derived quantities are essentially averaged over parameters derived from individual fits. We will also consider the application of this highly simplified approach.

Data Analysis The analysis of astrophysical observations will also benefit from the application of Bayesian techniques. One particularly pressing problem is the analysis of low count-rate observations. In this regime Normal (i.e., Gaussian) statistics are not applicable and different noise models and priors (e.g., Poisson and gamma distributions) must be considered. One important aspect of our proposed work will be using MHD (Guarrasi et al., 2014; Gudiksen et al., 2011) and hydrodynamic models (Warren & Winebarger, 2006) as a testing ground for assessing observational signatures and uncertainties. These models provide time-dependent distributions of temperature, density and velocity in multi-D spatial domains and allow the calculation of detailed line profiles including thermal and non-thermal broadening, and Doppler-shifts from bulk motions.

Schedule The proposed meeting schedule is three meetings at ISSI Bern, each three days in length, for a total of 108 person days (of the 120 maximum). The draft agenda for each meeting is as follows

Pre-meeting

- Determine the date for the first meeting and add young scientists to the team.
- Assemble several data sets from Hinode (EIS, XRT), SDO (AIA), SMM (BCS, FCS), SOHO (SUMER, CDS), and Chandra (HETG, MEG, LETG) to serve as a test bed for analysis. These data sets will be processed into higher level data products so that they may be widely analyzed. These data will also allow for the atomic data in different wavelength regions to be assessed (SXR, EUV, UV).
- Use available 3D MHD and 1D hydro models to synthesize observables. This will allow for comparisons between known temperature distributions and the results of inversions.
- Compute different realizations of atomic physics databases, by varying underlying atomic physics parameters.
- Distribute background material to participants.

Meeting 1

- Review talks for atomic physics, statistical inference, and data analysis.
- Discuss the application of hybrid Bayes and multiple imputation to the problem of inference in the presence of uncertainty in atomic physics parameters.
- Discuss observations at the limits of detection.
- Discuss inversion and other data analysis techniques.
- Discuss the application of these ideas to test data and simulated observables.

Meeting 2

- Review progress on the development of computer codes and the application to real and model data.
- Discuss how all of the uncertainties accumulate to limit inference.
- Direction for future work

Meeting 3

- Discuss peer-reviewed papers from the team and final results.
- Direction for future work and an overview paper.

The team does not anticipate writing a full review paper on this topic. Rather, team members will publish individual papers in the peer-reviewed literature. The team will consider writing an overview paper that describes the current best-practices for this class of problem. Every effort will be made to make the data and computer codes developed as part of this project publicly available.

Each meeting will require the standard ISSI support of providing a meeting room with projector, internet access, and white board. The standard ISSI financial support (per diem and accommodations) is also requested.

4 Team

Atomic Data			
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* Team leader/coordinator who will handle the administrative tasks.

5 References

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Warren, H. P., Winebarger, A. R., & Brooks, D. H. 2012, ApJ, 759, 141

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Education
1997 Diploma in Applied Mathematics from Ecole Polytechnique de Louvain, UCL, Belgium
2002 PhD in Statistics from Université catholique de Louvain, Belgium

Professional History
Since 2008, Senior Research Scientist, Royal Observatory of Belgium
2004 - 2008, Research Scientist, Royal Observatory of Belgium
2002 - 2004, Postdoc, Electrical and Computer Engineering department, Rice University, USA

Work Experience
Solar physicist with initial education in applied mathematics and statistics. Research interests include solar image processing and in particular supervised and unsupervised segmentation of solar images, solar irradiance, solar cycle studies, instrumental effect, flare prediction.

Synergistic Activities
- ROB-Lead for the FP7 SOLID project on the "First European Comprehensive Solar Irradiance Data Exploitation" (2012-2015)
- ROB Lead for the FP7 SOLARNET project on a "High resolution solar physics network" (2013-2017)
- PI of the PREDISOL project on "Characterization of active region's evolution in view of solar flare prediction" funded by the Belgian Research Action through Interdisciplinary Networks (BRAIN-be) (2014-2015)
- Leader, ISSI team on "Mining and Exploiting the NASA Solar Dynamics Observatory data in Europe" (2009-2011)
- Co-I on SDO Feature Finding Team (PI: Petrus Martens, 2008-2014). Development of an Active Region and a Coronal Hole feature recognition modules that are currently running in operational mode at LMSAL

Publications relevant to this proposal
K. Moon, J. Li, V. Delouille, F. Watson, A.O. Hero III, *Image patch analysis and clustering of sunspots: a dimensionality reduction approach* , IEEE International Conference on Image Processing, 2014 (Submitted),

C. Verbeeck, V. Delouille, B. Mampaey, R. De Visscher, *The SPoCA-suite: software for extraction, characterization, and tracking of Active Regions and Coronal Holes on EUV images*, Astronomy &Astrophysics, 561, 2014

C. Verbeeck, P. Higgins, T. Colak, F. Watson, V. Delouille, B. Mampaey, R. Qahwaji, *A multi-wavelength analysis of active regions and sunspots by comparison of automatic detection algorithms*, Solar Physics, 283, pp.67-95, 2011

P. Chainais, E. Koenig, V. Delouille, J.-F. Hochedez, *Virtual super resolution of scale invariant textured images using multifractal stochastic processes*, Journal of Mathematical Imaging and Vision , 39, pp.28-44, 2010

V. Delouille, P. Chainais, J.-F. Hochedez, *Spatial and Temporal Noise in Solar EUV Observations*, Solar Phys., 248, pp.441-455, 2008

P. Fryzlewicz, V. Delouille, G. Nason, *GOES-8 X-ray sensor variance stabilization using the multiscale data-driven Haar-Fisz transform*, Journal of the Royal Statistical Society, Series C, 56, pp.99-116, 2007

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March 15, 2014

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Education

Doctor of Philosophy, 1995, University of Chicago (Statistics under Prof XL Meng).

Bachelor of Science, 1991, Michigan State University (Statistics and Probability).

Professional Experience

Department of Mathematics, Imperial College London, Chair in Statistics (7/11 –).

Department of Statistics, University of California, Irvine, Chair (7/10 – 6/11), Professor (7/05 – 6/11), Associate Professor (7/03 – 6/05).

Department of Statistics, Harvard University, Associate Professor (7/00 – 6/03), Assistant Professor (7/96 – 6/00).

Honors and Awards

Elected Reviews Editor of *Journal of the American Statistical Association*, 2014 – 2016.

Wolfson Merit Award, August 2011 - July 2016.

Elected Fellow of the Institute of Mathematical Statistics, August 2010.

Elected Fellow of the American Statistical Association, August 2006.

Elected Editor of the *Journal of Computational and Graphical Statistics*, 2007 – 2009.

Research Interests

Professor van Dyk is an internationally recognized leader in the deployment of Bayesian statistical methods in astronomy and the physical sciences. He is particularly interested in highly structured models for complex sources and instruments, Bayesian methods for calibration uncertainty, model checking and selection, source and feature detection, Bayesian stellar evolution models, and computational techniques these methods require.

Selected Publications

1. van Dyk, D. A. (2014). The Role of Statistics in the Discovery of a Higgs Boson. *Annual Review of Statistics and Its Application*, **1**, 41–59.
2. Stenning, D.., Lee, T., van Dyk, D.., Kashyap, V., Sandell, J., and Young, C. (2013). Morphological Feature Extraction for Statistical Learning with Applications to Solar Images Data. *Statist Analysis & Data Mining*, **6**, 329–345.
3. Stein, N., van Dyk, D., *et al.* (2013). Combining Computer Models to Account for Mass Loss in Stellar Evolution. *Statistical Analysis & Data Mining*, **6**, 34–52.
4. Stein, N., Kashyap, V., Meng, X. L., and van Dyk, D. A. (2012). H-Means Image Segmentation to Identify Solar Thermal Features. In the *Proc. of the 19th IEEE Int'l Conf. on Image Processing, ICIP 2012* (Editor: E. Saber), 1597 - 1600.
5. Lee, H., Kashyap, V., van Dyk, D., Connors, A., Drake, J., Izem, R., Meng, X., *et al.* (2011). Accounting for Calibration Uncertainties in X-ray Analysis: Effective Areas in Spectral Fitting. *The Astrophysical Journal*, **731**, 126–144.
6. Park, Kashyap, Siemiginowska, van Dyk, *et al.* (2006). Hardness Ratios with Poisson Errors: Modeling & Computation. *Astrophysical Journal*, **652**, 610–628.
7. Protassov, R., van Dyk, D., *et al.* (2002). Statistics: Handle with Care, Detecting Multiple Model Components with the Likelihood Ratio Test. *The Astrophysical Journal*, **571**, 545–559.

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Selected Publications

Nathan M. Stein and Xiao-Li Meng. Practical Perfect Sampling Using Composite Bounding Chains: The Dirichlet-Multinomial Model. (2013). *Biometrika*, 100(4), 817-830.

Nathan M. Stein, David A. van Dyk, Ted von Hippel, Steven DeGennaro, Elizabeth J. Jeffery, and William H. Jefferys. (2013). Combining Computer Models to Account for Mass Loss in Stellar Evolution. *Statistical Analysis and Data Mining*, 6, 34-52.

Nathan Stein, Vinay Kashyap, Xiao-Li Meng, and David van Dyk. (2012). H-means Image Segmentation to Identify Solar Thermal Features. In *IEEE International Conference on Image Processing (ICIP)*. (student paper award finalist)

David A. van Dyk, Steven DeGennaro, Nathan Stein, William H. Jefferys, and Ted von Hippel. (2009). Statistical Analysis of Stellar Evolution. *The Annals of Applied Statistics*, 3, 117-143.

Ted von Hippel, William H. Jefferys, James Scott, Nathan Stein, Don E. Winget, Steven DeGennaro, Albert Dam, and Elizabeth Jeffery. (2006). Inverting Color-Magnitude Diagrams to Access Precise Star Cluster Parameters: A Bayesian Approach. *The Astrophysical Journal*, 645, 1436-1447.

Tutorials

Statistical Tools and Techniques for Solar Astronomers. *SolStat2012: Workshop on Solar Astronomy and Statistical Inference*, Harvard-Smithsonian Center for Astrophysics, February 2012. (co-taught with Alex Blocker)

Posters

Nathan Stein, Ted von Hippel, David van Dyk, Steven DeGennaro, Elizabeth Jeffery, and Bill Jefferys. Bayesian Inference for the White Dwarf Initial-Final Mass Relation. *Statistical Challenges in Modern Astronomy*, Penn State, June 2011.

Nathan Stein, David van Dyk, Alanna Connors, Aneta Siemiginowska, and Vinay Kashyap. LIRA: Low-Count Image Reconstruction and Analysis. *Chandra's First Decade of Discovery*, Boston, MA, September 2009.

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RESEARCH INTERESTS

Astrostatistics and cosmostatistics, topological data analysis, approximate Bayesian computation, generalized fiducial inference, linear mixed models, inverse function-based inference, inverse sensitivity analysis, applications to the physical sciences, foundations of statistics

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Visiting assistant professor, Department of Statistics, Carnegie Mellon University, Pittsburgh, PA, August 2012 - present
Graduate student fellow, Statistical and Applied Mathematical Sciences Institute (SAMSI), Research Triangle Park, NC. Program: Uncertainty Quantification (Fall 2011, Spring 2012)

RESEARCH PAPERS

- D. Hammerling, M. Cefalu, **J. Cisewski**, F. Dominici, G. Parmigiani, C. Paulson, R.L. Smith, Completing the Results of the 2013 Boston Marathon (Accepted for publication in *PLOS ONE*).
- **J. Cisewski**, R. A. C. Croft, P. E. Freeman, C. R. Genovese, M. Özbek, and L. Wasserman, Nonparametric 3D map of the IGM using the Lyman-alpha forest (Accepted for publication in *Monthly Notices of the Royal Astronomical Society*).
- **J. Cisewski** and J. Hannig, Generalized fiducial inference for normal linear mixed models (2012), *The Annals of Statistics*, **40**, 10, pp. 2102 – 2127.
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- **J. Cisewski**, E. Snyder, J. Hannig, and L. Oudejans, Support vector machine classification of unknown powders using laser induced breakdown spectroscopy (LIBS) spectral data (2012), *Journal of Chemometrics*. doi: 10.1002/cem.2422.
- S. Yeo, **J. Cisewski**, E. Lock, J. S. Marron, Exploratory Analysis of Exercise Adherence Patterns with Sedentary Pregnant Women (2010), *Nursing Research*, **59**, pp. 280 – 287.

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EDUCATION

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SOME RELEVANT PUBLICATIONS

Stenning, D.C., Lee, T.C.M., van Dyk, D.A., **Kashyap, V.**, Sandell, J., & Young, C.A., 2013, Stat. Analysis and Data Mining, 6, 329 *Morphological feature extraction for statistical learning with applications to solar image data*

Yu, Y., van Dyk, D.A., **Kashyap, V.L.,** & Young, C.A., 2012, Sol.Phys., 281, 847 *A Bayesian Analysis of the Correlations Among Sunspot Cycles*

Lee, H., **Kashyap, V.L.,** van Dyk, D.A., Connors, A., Drake, J., Izem, R., Meng, X.-L., Min, S., Park, T., Ratzlaff, P., Siemiginowska, A., & Zezas, A., 2011, ApJ, 731, 126 *Accounting for Calibration Uncertainties in X-ray Analysis: Effective Areas in Spectral Fitting*

Kashyap, V.L., van Dyk, D.A., Connors, A., Freeman, P.E., Siemiginowska, A., Xu, J., & Zezas, A., 2010, ApJ, 719, 900 *On Computing Upper Limits to Source Intensities*

Kashyap, V.L., Lee, H., Siemiginowska, A., McDowell, J., Rots, A., Drake, J., Ratzlaff, P., Zezas, A., Izem, R., & Connors, A., 2008, SPIE, 7016, 21 *How to handle calibration uncertainties in high-energy astrophysics*

Kashyap, V.L., Drake, J.J., & Saar, S.H., 2008, ApJ, 687, 1339 *Extrasolar Giant Planets and X-ray Activity*

Kashyap, V.L., Drake, J.J., Güdel, M., & Audard, M., 2002, ApJ, 580, 1118 *Flare Heating in Stellar Coronae*

Protassov, R., van Dyk, D.A., Connors, A., Kashyap, V.L., & Siemiginowska, A., 2002, ApJ, 571, 545 *Statistics, Handle with Care: Detecting Multiple Model Components with the Likelihood Ratio Test*

Freeman, P.E., **Kashyap, V.**, Rosner, R., & Lamb, D.Q., 2002, ApJS, 138, 185 *A Wavelet-Based Algorithm for the Spatial Analysis of Poisson Data*

van Dyk, D.A., Connors, A., **Kashyap, V.L.**, & Siemiginowska, A., 2001, ApJ, 548, 224 *Analysis of Energy Spectra with Low Photon Counts via Bayesian Posterior Simulation*

Kashyap, V., & Drake, J.J., 1998, ApJ, 503, 450 *Markov-Chain Monte Carlo Reconstruction of Emission Measure Distributions: Application to Solar Extreme-Ultraviolet Spectra*

Dr. Frédéric Auchère

Born 1974 November 13 in Paris, France
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Curriculum Vitæ

Dr. F. Auchère's main research interests are the physics of the corona and the solar wind, the variability of the solar irradiance, and the development of innovative plasma diagnostics for remote sensing observations. He has over 15 years' experience of working on solar data and has extended expertise on the design, calibration and operations of space instruments. He is PI of the EIT instrument on board *SOHO* and co-PI of the EUI instrument suite on *Solar Orbiter*. He is PI of the HECOR EUV coronagraph on the Herschel sounding rocket payload and Co-PI of the CLASP sounding rocket spectro-polarimeter.

Positions Held

Since 2006	Assistant Astronomer - Institut d'Astrophysique Spatiale (IAS), Orsay, France
2003-2005	Post-doctoral fellow - IAS, Orsay, France
1998-2002	EIT support scientist - NASA/Goddard Space Flight Center (GSFC), Greenbelt, MD

Education

Université Pierre et Marie Curie, Paris VI	
2000	Ph.D. Thesis: *"An Observational Study of Coronal Helium Using the EIT Instrument on Board the SOHO Spacecraft".* Obtained with the highest honors
1997	Graduate Degree in plasmas physics, with honors
1996	Master of Science in theoretical physics

Selected Publications

Auchère, F. Bocchialini, K., Solomon, J, Tison, E. 2014, *''Long Period Intensity Pulsations in the Solar Corona During Activity Cycle 23''*, A&A, 563, A8

Barbey, N., Guennou, C. & **Auchère, F.** 2013, *''TomograPy: A Fast, Instrument-Independent, Solar Tomography Software''*, Sol. Phys., 283(1), 227

Guennou, C., **Auchère, F.**, Soubrié, E., et al. 2013, *''Can the Differential Emission Measure constrain the timescale of energy deposition in the corona? ''*, ApJ, 774,31

Guennou, C., **Auchère, F.**, Soubrié, E., et al. 2012, *''On the Accuracy of the Differential Emission Measure Diagnostics of Solar Plasmas. Application to AIA/SDO. Part II: Multithermal plasmas''*, ApJS, 203, 25

Barbey, N., **Auchère, F.**, Rodet, T., & Vial, J.-C. 2008, *"A Time-Evolving 3D Method Dedicated to the Reconstruction of Solar Plumes and Results Using Extreme Ultraviolet Data"*, Solar Physics, 248, 409

Dudok de Wit, T. & **Auchère, F.** 2006, *"Multispectral analysis of solar EUV images: linking temperature to morphology"*, 466(1), 3475

Auchère, F. 2005, *"Effect of the H I Lyman α chromospheric flux anisotropy on the total intensity of the resonantly scattered coronal radiation"*, ApJ, 622, 737

Auchère, F. et al. 2005, *"The heliospheric He II 30.4 nm solar flux during solar cycle 23"*, ApJ, 625, 1036

Zhukov, A. & **Auchère, F.** 2004, *"On the initiation of CMEs manifested by EIT waves and EUV dimmings''*, Astronomy & Astrophysics, 427, 705

F. Reale

EDUCATION: 1987-1990 PhD in Physics, University of Palermo, Italy;1980-1985 Laurea (Master degree) in Physics, University of Palermo, Italy

RESEARCH/ACADEMIC EXPERIENCE: 2001 - Now Associate Professor, University of Palermo, Italy; 1992 - 2001 Researcher, permanent position, University of Palermo, Italy

MAIN PROJECT ROLES and EXPERIENCE: Associate scientist of UltraViolet Coronagraphic Spectrometer (UVCS) on-board the SoHO mission; Co-I of the Solar Photometer in X-rays (SphinX) on-board the CORONAS-PHOTON satellite. PI of HPC projects at the CINECA facility since 1985, and of one european PRACE project of about 30 million CPU hours in 2012. He collaborates with groups at International science centers, such as the Harvard-Smithsonian Center for Astrophysics (USA) and the Enrico Fermi Institute of the University of Chicago (USA). LOC Chairman, SOC member, Editor: International Solar Physics Meeting "Hinode4: unsolved problems and recent insights", 11-15 Oct. 2010, Palermo; Main Scientific Organizer: Event E23: New Perspectives on the Solar-Stellar Connection, 38th COSPAR Scientific Assembly, Bremen, Germany, 18-25 July 2010, Jul 18, 2010; Steering Committee Chairman of "Coronal Loops Workshops". Referee for the Astrophysical Journal, Astronomy & Astrophysics, Solar Phys., Nature, Monthly Not. of the Royal Astron. Soc., J. of Geophys. Res.

PUBLICATIONS: Main topics: solar and stellar coronal physics, interstellar medium, numerical astrophysics. As of end of 2013, author of about 270 publications of which about 130 ISI publications (between 1985 and 2013) in Science (first author of 2 papers), and most in the Astrophysical Journal, and Astronomy & Astrophysics; 1 Living Review in Solar Physics. Of the ISI publications, 5 as single author, 41 as first author. Refereed papers have over 2800 ISI (3500 on Google Scholar) citations, the ISI H-index is 29 (34 on Google Scholar).

Selected Publications

- Reale F (2010). Coronal Loops: Observations and Modeling of Confined Plasma. LIVING REVIEWS IN SOLAR PHYSICS, vol. 7

- Reale F, Testa P, Klimchuk JA, Parenti S (2009). Evidence Of Widespread Hot Plasma In A Nonflaring Coronal Active Region From Hinode/X-Ray Telescope. THE ASTROPHYSICAL JOURNAL, vol. 698, p. 756-765

- Reale F, Orlando S (2008). Nonequilibrium of ionization and the detection of hot plasma in nanoflare-heated coronal loops. THE ASTROPHYSICAL JOURNAL, vol. 684, p. 715-724

- Reale F, Parenti S, Reeves KK, Weber M, Bobra MG, Barbera M, Kano R, Narukage N, Shimojo M, Sakao T, Peres G, Golub L (2007). Fine thermal structure of a coronal active region. SCIENCE, vol. 318, p. 1582-1585

- Reale F, Ciaravella A (2006). Analysis of a multi-wavelength time-resolved observation of a coronal loop. ASTRONOMY & ASTROPHYSICS, vol. 449, p. 1177-1192

- Reale F (2002). More on the determination of the coronal heating function from Yohkoh data. THE ASTROPHYSICAL JOURNAL, vol. 580, p. 566-573

- Reale F, Peres G (2000). Trace-derived temperature and emission measure profiles along long-lived coronal loops: The role of filamentation. THE ASTROPHYSICAL JOURNAL, vol. 528, p. L45-L48

Curriculum Vitae

Personal

Name: Giulio Del Zanna
Address: Department of Appled Mathematics and Theoretical Physics (DAMTP)
University of Cambridge, Wilberforce Road, Cambridge, CB3 0WA UK
E-mail: gd232@cam.ac.uk

Present Employment

Senior Research Associate, DAMTP, University of Cambridge, UK.
Co-I of the STFC DAMTP astrophysics grant, and of the SOLID EU FP7 grant.

Employment History

19 Oct 2012 –	Senior Research Associate, DAMTP, University of Cambridge, UK.
Dec 2008 – Oct 2012:	STFC Advanced Fellow, DAMTP, University of Cambridge, UK.
Jul 2007 – Nov 2008:	PPARC Advanced Fellow at MSSL, University College London, UK.
Oct 2004 – Jun 2007:	Research Fellow at MSSL, University College London, UK.
Apr 2002 – Sept 2004:	Research associate at DAMTP, University of Cambridge, UK.
Oct 2001 – Dec 2001:	Research associate at the University of Florence, Italy.
Dec 1999 – Aug 2001:	Research associate at DAMTP, University of Cambridge, UK.
Jul 1999 – Nov 1999:	Research fellow, Centre for Astrophysics, University of Central Lancashire.

Academic Qualifications

Ph.D. in astrophysics, Jul 1999, University of Central Lancashire, UK.
Ph.D. thesis: *'Extreme Ultraviolet Spectroscopy of the Solar Corona'*.

Degree in Physics, University of Florence, with major in Astrophysics, Nov 1994.
Thesis: '*EUV spectroscopy of stellar coronae*'.

Awards

2010: RAS group achievement award for geophysics.

2007-2012: PPARC/STFC Advanced Fellowship.

1995-1998: Three year studentship at the University of Central Lancashire, UK.

Randall Smith

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Education

Ph.D. Physics, 1996, University of Wisconsin, Madison, Wisconsin

B.S. Math/Physics, 1991, Carnegie Mellon, Pittsburgh, Pennsylvania

Current Position

Smithsonian Astrophysical Observatory, Cambridge, Massachusetts

Astrophysicist 2008 - present

Previous Positions

Johns Hopkins University, Physics & Astronomy, Research Scientist	2004-2008
Smithsonian Astrophysical Observatory, Astrophysicist	1997-2004
NASA Goddard Space Flight Center NRC Post-doctoral Fellow	1996-1997

Interests

Since 2007, I have authored or co-authored over 60 refereed publications and given 12 invited talks, covering a range of topics. Given my work on X-ray satellite development, a key duty is maintaining a field-wide perspective of the science priorities and their impact on mission requirements and capabilities. Much of my research time is devoted to creating models of X-ray spectra by building an atomic database (AtomDB) together with models of collisional plasmas. My individual research focuses on processes and components in the interstellar medium, including the formation, growth, and composition of interstellar grains as revealed by X-ray scattering, the origin of the soft X-ray background, including both the local hot bubble and solar wind charge exchange, understanding the origin of mixed-morphology supernova remnants from both observational and theoretical modeling, and ISM studies via absorption spectroscopy of X-ray binaries. I also work on other topics involving X-ray spectroscopy, including studying accretion processes in symbiotic stars and other compact sources. Finally, I have recently developed an interest in studying quiescent and flaring solar X-rays at high spectral resolution.

Professional Responsibilities

Secretary, High Energy Astrophysics Division of the American Astronomical Society	2012-present
Member, SAO Professional Accomplishments Evaluation Committee (11-13)	2013-present
Chair, COSPAR Panel on Capacity-Building Workshop Fellowship Program	2010-present
Member, Astro-H Science Office	2010-present
Member, Chandra Users' Committee	2006-2008

Inigo Arregui

Nationality: Spanish
Position: Researcher Instituto de Astrofisica de Canarias (Spain)

Education:
2003 Ph.D. Physics - Universitat de les Illes Balears (UIB), Spain
2001 M.Sc. Physics - Universitat de les Illes Balears (UIB), Spain
1997 B.Sc. Physics - Universidad de La Laguna, Spain

Fields of Study:
Physics - Physics of Fluids: Magneto-Fluid Dynamics, Physics of Plasmas
Astronomy & Astrophysics - Solar System: Solar Physics, The Sun
Mathematics: Probability - Application of Probability

Research Interests:
Magnetic Structuring of the Solar Corona - Magnetohydrodynamic Wave Theory - Solar Atmospheric Seismology - Heating of Magnetized Plasmas - Bayesian Analysis

Career:
Present: Ramón y Cajal Researcher (tenure track), Instituto de Astrofisica de Canarias (IAC), Spain
2012: Visiting Associate Professor, Japan Aerospace Exploration Agency (ISAS/JAXA), Japan
2006-2011: Postdoctoral Researcher, Universitat de les Illes Balears (UIB), Spain
2004-2006: Postdoctoral Researcher, Centrum voor Plasma Astrofysica, K.U. Leuven, Belgium
1998-2003: PhD, MHD waves in the solar atmosphere, Universitat de les Illes Balears (UIB), Spain

Research Projects:
Participated in 11 research projects with national and international funding: 2 as PI from Spanish Ministry of Economy and Competitiveness (2012-2017) and from UIB, Spain (2009). 7 as member from Spanish Ministry of Science (2000-2014). 1 as member from the K.U. Leuven (2004-2008). 1 as member of the European Commission PLATON Network (2000-2004).

Selected Publications: from a total of 38 articles in SCI journals
- I. Arregui, & A. Asensio Ramos (2014): "Determination of the Cross-Field Density Structuring in Coronal Waveguides using the Damping of Transverse Waves", Astronomy & Astrophysics, accepted.
- I. Arregui, A. Asensio Ramos, & A. J. Díaz (2013): "Bayesian Analysis of Multiple Harmonic Oscillations in the Solar Corona", The Astrophysical Journal Letters, 765, L23.
- I. Arregui, A. Asensio Ramos, & D. J. Pascoe (2013): "Determination of Transverse Density Structuring from Propagating Magnetohydrodynamic Waves in the Solar Atmosphere', The Astrophysical Journal Letters, 769, L34.
- I. Arregui, R. Oliver, J. L. Ballester (2012): "Prominence Oscillations". Living Reviews in Solar Physics, 9, 2
- I. Arregui (2012): "Inversion of Physical Parameters in Solar Atmospheric Seismology", in "Multi-scale Dynamical Processes in Space and Astrophysical Plasmas", Astrophysics and Space Science Pro- ceedings, 31, Leubner, Manfred P.; Voros, Zoltan (Eds.).
- I. Arregui, A. Asensio Ramos (2011): "Bayesian Magnetohydrodynamic Seismology of Coronal Loops", The Astrophysical Journal, 740, 44.

MARK A. WEBER, Ph.D. — CURRICULUM VITAE

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EDUCATION & EMPLOYMENT

2002–present	**Astrophysicist**, Smithsonian Astrophysical Observatory
2000–02	**Postdoctoral Fellow**, Stanford University
2000	**Doctorate of Philosophy**, Physics, Montana State University—Bozeman
1995	**Master of Science**, Physics, Montana State University—Bozeman
1991	**Bachelor of Science** (with Honors), Physics, Harvey Mudd College

RESEARCH INTERESTS

Energy storage and release in coronal structures; temperature diagnostics in optically thin plasmas; organization and evolution of magnetic field structures in the corona; calibration of solar imaging instruments

SELECTED RELEVANT EXPERIENCE

Experienced with data analysis, calibration, and operation for solar instrumentation: *Hinode*/**XRT** (X-Ray Telescope) **Project Scientist** (2006–2008, including launch and commissioning) and **Instrument Team** (2002–present); **SDO/AIA** (Atmospheric Imaging Assembly) **SAO Project Scientist** 2008–present) and **Instrument Team** (2005–present); **TRACE** (Transition Region and Coronal Explorer) **SAO Project Scientist** 2006–2008) and **Instrument Team** (2002–2010); **IRIS** (Interface Region Imaging Spectrograph) **Instrument Team** (2007–present); *Yohkoh*/**SXT** (Soft X-ray Telescope) **Instrument Team** (1995–1999)

SELECTED RELEVANT PAPERS

- "Isothermal Bias of Filter Ratio Method of Observations of Multithermal Plasma", **Weber, M.A.**; Schmelz, J.T.; DeLuca, E.E.; Roames, J.K.; 2005, *The Astrophysical Journal* **635**, L101.
- "Calibrating Data from the Hinode/X-Ray Telescope and Associated Uncertainties", Kobelski, A.R.; Saar, S.H.; **Weber, M.A.**; McKenzie, D.E.; Reeves, K.R.; 2014, *Solar Physics Online First*, DOI 10.1007/s11207-014-0487-9.
- "Energy Release in the Solar Corona from Spatially Resolved Magnetic Braids", Cirtain, J W.; Golub, L.; Winebarger, A.R.; de Pontieu, B.; Kobayashi, K.; Moore, R.L.; Walsh, R.W.; Korreck, K.E.; **Weber, M.**; McCauley, P.; Title, A.; Kuzin, S.; Deforest, C.E.; 2013, *Nature* **493**, 501.
- "Off-limb Solar Coronal Wavefronts from SDO/AIA Extreme-ultraviolet Observations-Implications for Particle Production", Kozarev, K.A.; Korreck, K.E.; Lobzin, V.V.; **Weber, M.A.**; Schwadron, N. A.; 2011, *The Astrophysical Journal Letters* **733**, L25.
- "SDO/AIA response to coronal hole, quiet Sun, active region, and flare plasma", O'Dwyer, B.; Del Zanna, G.; Mason, H.E.; **Weber, M.A.**; Tripathi, D; 2010, *Astronomy and Astrophysics* **521**, id.A21.
- "Some Like It Hot: Coronal Heating Observations from Hinode X-ray Telescope and RHESSI", Schmelz, J.T.; Kashyap, V.L.; Saar, S.H.; Dennis, B.R.; Grigis, P.C.; Lin, L.; De Luca, E.E.; Holman, G.D.; Golub, L.; and **Weber, M.A.**, 2009, *The Astrophysical Journal* **704**, 863.
- "An On-Orbit Determination of the On-Axis Point Spread Function of the Hinode X-Ray Telescope", **Weber, M.**; Deluca, E.E.; Golub, L.; Cirtain, J.; Kano, R.; Sakao, T.; Shibasaki, K.; Narukage, N.; 2007, *Publications of the Astronomical Society of Japan* **59**, S853.
- "Evidence for Alfvén Waves in Solar X-ray Jets", Cirtain, J.W., Golub, L., Lundquist, L., van Ballegooijen, A., Savcheva, A., Shimojo, M., DeLuca, E., Tsuneta, S., Sakao, T., Reeves, K., **Weber, M.**, Kano, R., Narukage, N., and Shibasaki, K., 2007, *Science* **318**, 1580.

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Education

1994	Ph.D., *Plasma Physics*, Columbia University, New York, New York
1989	B.S., *Physics*, College of William and Mary, Williamsburg, Virginia

Awards and Honors

2004	American Astronomical Society/Solar Physics Division Karen Harvey Prize for early career achievement in solar physics
2004	NRL Alan Berman Research Publication Award
1994	Sigma Xi, Columbia University
1989	Phi Beta Kappa, College of William and Mary

Experience

2002 –	*Astrophysicist, Naval Research Laboratory*
1998 – 2002	*Astrophysicist, Smithsonian Astrophysical Observatory*
1995 – 1998	*Postdoctoral Research Scientist, Naval Research Laboratory*

Journal Publications

–2014–

Warren, H. P., Measurements of Absolute Abundances in Solar Flares, *Astrophys. J.*, *in press*, 2014.

Ugarte-Urra, I. and H. P. Warren, Determining Heating Timescales in Solar Active Region Cores from AIA/SDO Fe XVIII Images, *Astrophys. J.*, 783, 12, 2014.

Boerner, P. F., P. Testa, H. Warren, M. A. Weber, and C. J. Schrijver, Photometric and Thermal Cross-calibration of Solar EUV Instruments, *Sol. Phys.*, 289, 2377, 2014.

–2013–

Warren, H. P., J. T. Mariska, and G. A. Doschek, Observations of Thermal Flare Plasma with the EUV Variability Experiment, *Astrophys. J.*, 770, 116, 2013.

Brooks, D. H., H. P. Warren, I. Ugarte-Urra, and A. Winebarger, High Spatial Resolution Observations of Loops in the Solar Corona, *Astrophys. J.*, 772, 18, 2013.

Sheeley, N. R., S. F. Martin, O. Panasenco, and H. P. Warren, Using Coronal Cells to Infer the Magnetic Field Structure and Chirality of Filament Channels, *Astrophys. J.*, 772, 88, 2013.

Doschek, G. A., H. P. Warren, and G. A. Doschek, Chromospheric Evaporation in an M1.8 Flare Observed by the Extreme-ultraviolet Imaging Spectrometer on Hinode, *Astrophys. J.*, 767, 55, 2013.

Young, P. R., G. A. Doschek, H. P. Warren, and H. Hara, Properties of a Solar Flare Kernel Observed by Hinode and SDO, *Astrophys. J.*, 766, 127, 2013.

–2012–

Warren, H. P., A. R. Winebarger, and D. H. Brooks, A Systematic Survey of High Temperature Emission in Solar Active Regions, *Astrophys. J.*, 759, 141, 2012.