Astronomical Data Analysis VII

Book of Abstracts

FOREWORD

Held regularly since 2001, the ADA conference series is focused on algorithms and information extraction from astrophysical data sets. The program includes keynote, invited and contributed talks, as well as posters. This conference series has been characterized by a range of innovative themes, including multiscale geometric transforms such as the curvelet transform, compressed sensing and clustering in cosmology, while at the same time remaining closely linked to front-line open problems and issues in astrophysics and cosmology.
One session will be dedicated to the advanced algorithms in astronomical project pipeline. Other sessions will include asteroseismology, exoplanet detection, large scale structures (weak lensing, galaxy catalogs), CMB (source separation, polarization), restoration (map-making, deconvolution, modeling), hyperspectral data analysis, compressed sensing.
The ADA conference is a strongly interdisciplinary conference allowing researchers coming from different fields to interact. We generally have 5 or 6 keynote speakers, who are leaders in their respective fields, half being astronomers and the other being mathematicians, statisticians or electrical engineering researchers. Each session has at least one invited speaker, and half of the talks are contributed talks. A full poster session is also regularly included in the program, where each researcher with a poster has a 2mn oral talk, allowing him to present himself, his results and invite other participants to view his poster.

ADA V KEYNOTE SPEAKERS

Martha P. Haynes, Cornell University, USA (HI Survey, ALFALFA project)
Francois Bouchet, IAP, Paris, France (CMB, Planck project)
Masahiro Takada, IPMU, Tokyo, Japan (Weak Lensing)
Pavlos Protopapas, CFA Harvard, USA (Time Series, periodic variable stars, Quasar Light Curves, etc)
Gabriel Peyre , Paris Dauphine, France (Sparsity, Dictionary Learning, Inverse Problems)
Jalal Fadili, Caen University, France (Optimization, Inverse problems, Poisson noise)
Mike Hobson, Cambridge (Bayesian Astronomical Data Analysis)
Yves Wiaux, EPFL, Switzerland, (Compressed Sensing)

ADA V INVITED SPEAKERS

Jogesh Babu, Penn State University, USA (Bayesian versus Frequentist)
Roberto Trotta, Imperial College London, UK (Bayesian Cosmology, Supernovae, etc)
Enrique Martinez, Inst de Física de Cantabria, Santander, Spain (CMB, Non Gaussianity)
Adrienne Leonard, CEA (Weak lensing),
Benjamin Joachimi, Edimburgh Univ, (Weak lensing)

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CONFERENCE PROGRAM

Note:
[KS] = Keynote Speaker (50min)
[IS] = Invited Speaker (30min)

Monday 14 May 2012 : **Session 1: Map Making** **Session Chair: Mike Hobson**			
From	**To**	**Speaker**	**Topic**
14:00	14:15		Welcome
14:15	**15:05**	**Yves Wiaux [KS]**	**Sparsity Averaging Reweighted Analysis (SARA): a novel algorithm for radio-interferometric imaging**
15:05	15:25	Stefan J. Wijnholds	Self-Calibration of Irregular Synthesis Arrays Using Redundancy Calibration
15:25	15:45	Didier Vibert	Dynamic 3D Tomographic reconstruction of the electronic density in the Solar Corona from LASCO chronograph images using TV regularization with a large scale splitting.
15:45	16h05	Jianfeng Zhou	Angular Resolution and Cross-Correlation
16:05	**16:30**	**Coffee Break**	
Session 2: Bayesian Methods I **Session Chair: Albert Bijaoui**			
16:30	**17:30**	**Mike Hobson [KS]**	**Nets and nests: accelerated Bayesian inference in astrophysics**
17:30	**18:00**	**Roberto Trotta [IS]**	**Bayesian hierarchical models for supernova cosmology**
18:00	18:30	Poster Presentations (2min each poster)	
18:30	**19:00**	**Poster Session**	
19:00	**20:30**	**Cocktail**	

Tuesday 15 May 2012: **Session 3: Sparsity I** **Session Chair: Yves Wiaux**			
From	**To**	**Speaker**	**Topic**
9:00	**9:50**	**Gabriel Peyre [KS]**	**Learning Sparse Representations**
9:50	10:10	Jason McEwen	Implications of a new sampling theorem for sparse signal reconstruction on the sphere
10:10	10:30	Simon Beckouche	Dictionary Learning and Astronomical Image Restoration
10:30	**11:00**	**Coffee Break**	
Session 4: Bayesian Methods II **Session Chair: Jalal Fadili**			
11:00	**11:30**	**Joguesh Babu [IS]**	Bayesian and Frequentist approaches
11:30	11:50	Thomas Rodet	A gradient-like variational Bayesian approach for unsupervised extended emission map-making from SPIRE/ Herschel data
11:50	12:10	Albert Bijaoui	A global strategy for spectral inversion from a model library
12:10	14:00	**LUNCH BREAK**	
		BREAK	
16:00	**16:30**	**Coffee Break**	
Session 5: Sparsity II **Session Chair: Gabriel Peyre**			
16:30	17:20	**Jalal Fadili [KS]**	**Inverse Problems with Poisson Noise: a Sparsity and Optimization Tour**
17:20	17:40	Sylvia Paris	MAP-based sparse detection strategies. Application to the hyperspectral data of the MUSE instrument
17:40	18:00	Jerome Bobin	Source separation for high quality CMB estimation

Wednesday 16 May 2012:
Session 6: Pipeline
Session Chair: Ralf Siebenmorgen

From	To	Speaker	Topic
9:00	**9:50**	**Martha P. Haynes [KS]**	**The ALFALFA Census of Gas-Bearing Galaxies at z=0**
9:50	10:10	Vianney Lebouteiller	The Cornell Atlas of Spitzer Spectra and the recent advances in the extraction of complex sources
10:10	10:30	Dina Said	Automatic Identification of Faults in Radio Astronomical Surveys
10:30	**11:00**	**Coffee Break**	
11:00	11:20	Alberto Krone-Martins	Unsupervised Photometric Membership Assignment in Stellar Clusters
11:20	11:40	Frederic Raison	Detection of polarization effects in Gaia data
11:40	12:00	Antoine Llebaria	Revealing long term features on synoptic maps of the Sun corona
12:00	12:20	Jean-Francois Hochedez	Reconstructing the non shift-invariant non-axisymmetric evolving PSF of the SODISM telescope onboard the PICARD space mission
12:20	14:00	**LUNCH BREAK**	
14:00	**19:00**	**Trip**	
20:30	**00:00**	**Conference Dinner**	

Thursday 17 May 2012: Session 7: LSS & Weak Lensing Session Chair: Jean-Luc Starck			
From	**To**	**Speaker**	**Topic**
9:00	**9:50**	**Masahiro Takada [KS]**	**Weak Lensing**
9:50	**10:20**	**Adrienne Leonard [IS]**	A compressed sensing approach to 3D weak lensing
10:20	10:40	Natallia Karpenka	Bayesian constraints on dark matter halo properties using gravitationally-lensed supernovae
10:40	**11:10**		**Coffee Break**
11:10	**11:40**	**Benjamin Joachimi [IS]**	Back to normal - Box-Cox transformations in cosmology
11:40	12:00	François-Xavier Dupé	Tomographic detection of the ISW signal
12:00	12:20	Antoine Labatie	Model-dependent covariance matrix for the study of Baryon Acoustic Oscillations
12:20	12:40	Daniel M. Bramich	Systematic Trends In Sloan Digital Sky Survey Photometric Data
12:40	**16:30**	**Break**	
Session 8: Time Series Session Chair: Joguesh Babu			
16:00	**16:30**	**Coffee Break**	
16:30	**17:20**	**Pavlos Protopapas [KS]**	**Interdisciplinary Science in Astronomy: A review**
17:20	17:40	Maria Süveges	False Alarm Probability for periodogram peaks based on bootstrap and extreme-value techniques
17:40	18:00	Giuseppe Greco	Evidence of Chaotic Dynamics in Gamma Ray Burst Explosions
18:20	18:40	Holger Pletsch	Blind searches for gamma-ray pulsars with Fermi LAT
18:40	19:00	Ra Inta	Sparse methods for improving gravitational wave detection

Friday 18 May 2012: Session 9: CMB Session Chair: Enrique Martinez			
From	**To**	**Speaker**	**Topic**
09:00	**9:50**	**Francois Bouchet [KS]**	**CMB, from Gamow to Planck**
9:50	10:10	Paniez Paykari	True CMB Power Spectrum Estimation
10:10	10:30	Laurence Perotto	Reconstructing the CMB lensing on PLANCK-like temperature maps
10:30	10:50	Raúl Fernández-Cobos	Multi-resolution internal template cleaning: An application to the CMB polarization data
10:50	**11:20**		**Coffee Break**
Session Chair: Francois Bouchet			
11:20	**11:50**	**Enrique Martinez [IS]**	**CMB and Non Gaussianity**
11:50	12:10	Florent Sureau	Compact Sources Removal for Full-Sky CMB Data using Sparsity
12:10	12:30	Biuse Casaponsa	Neural network estimator to measure local non-Gaussianity in CMB
12:30	12:50	Luis Fernando Lanz	Extragalactic point source detection in WMAP 7-year data at 61 and 94 GHz
12:50		**END**	

Poster Presentations

The following posters will be displayed throughout the duration on the conference.

Presenter	Poster Title
Didier Vibert	EMphot: Photometric Software with Bayesian Priors. Application to GALEX
Huo Zhuoxi	Image Reconstruction with accelerated direct demodulation method for HXMT
Wei Zheng	APLUS: A Data Reduction Pipeline for HST/ACS and WFC3 images
Frederic Raison	Markov chain Monte Carlo (MCMC) with parallel tempering to calibrate Gaia's radiation damage model
Jeremy Rapin	Robust Non-Negative Matrix Factorization for Multispectral Data with Sparse Priors
Rafael Carrillo	A novel convex optimization approach for optical interferometric imaging
Daniel Machado	Spectral Redshift Estimation using PCA and Wavelet Denoising
Sandrine Pires	A wavelet-based approach to computation of weak lensing statistics
Viviana Acquaviva	Understanding the Spectral Energy Distribution of galaxies
Tuhin Ghosh	Spectral Characterisation of CMB Foregrounds
Maria Suveges	Automated cross-survey classifications: variable objects in LINEAR with Hipparcos training set

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ABSTRACTS – ORAL CONTRIBUTIONS

Monday 14 May 2012

Sparsity Averaging Reweighted Analysis (SARA): a novel algorithm for radio-interferometric imaging

R. Carrillo (1), J. D. McEwen (2), and Y. Wiaux (1,3)

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We discuss a novel algorithm for image reconstruction in radio interferometry. The regularization of the ill-posed inverse problem, induced by the incomplete Fourier sampling provided by the visibility measurements, relies on the assumption of average signal sparsity over representations in multiple wavelet bases. The algorithm, defined in the versatile framework of convex optimization, is dubbed Sparsity Averaging Reweighted Analysis (SARA). We show through simulations that the proposed approach largely outperforms state of the art imaging methods in the field, all based on the assumption of signal sparsity in a single basis.

Self-Calibration of Irregular Synthesis Arrays Using Redundancy Calibration

Stefan J. Wijnholds (Netherlands Institute for Radio Astronomy)

Redundancy calibration exploits the fact that regular arrays have many redundant baselines, i.e., that regular arrays observe the same spatial frequencies with different pairs of antennas. This allows self-calibration without the need for a sky model, making it a valuable tool for radio telescope arrays with redundant baselines, such as the Westerbork Synthesis Radio Telescope (WSRT) and the Low Frequency Array (LOFAR) high-band antenna stations. In this presentation, I address the application of this powerful technique to approximately redundant baselines in irregular synthesis array configurations. I illustrate this with results obtained from actual observations with fully randomized LOFAR low-band antenna configurations. The promising results indicate that redundancy based self calibration may play a crucial role in future radio telescopes and particularly in the Square Kilometre Array.

Dynamic 3D Tomographic reconstruction of the electronic density in the Solar Corona from LASCO chronograph images using TV regularization with a large scale splitting proximal algorithm.

Didier Vibert (1), Richard Frazin (2), Antoine Llebaria (1), Philippe Lamy (1)

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We present a new approach to reconstruct the time-varying 3D electronic density in the solar corona from LASCO chronograph images using solar rotation tomography. This problem is largely ill-posed by nature and taking into account the time variation without increasing the size of the observed data set leads to a massively under-determined system needing a strong amount of regularization. Up to now only L2-norm Tikhonov-like regularization of the least-square solution were applied. Due to the emergence of efficient L1-norm minimization algorithm targeting large scale problems without loosing accuracy , we were able to apply a proximal splitting method to achieve a TV spatial-temporal regularization of the least-square minimization. We end up with an inversion preserving better the sharp features in the corona.

Angular Resolution and Cross-Correlation

Jianfeng Zhou (Center for Astrophysics, Tsinghua University, China)

Usually, the angular resolution of a telescope can be estimated by the Rayleigh criterion : Two point sources are regarded as just resolved when the principal diffraction maximum of one image coincides with the first minimum of the other. Modern image processing techniques including deconvolution of the point spread function allow better resolution. Here, we present a new definition of angular resolution based on the concept of correlation. In imaging system, the definition is compatible to the Rayleigh criterion. In deconvolution, the definition will also help us to quantitatively estimate the angular resolution of the resulted image.

Nets and nests: accelerated Bayesian inference in astrophysics

Michael Hobson
Cavendish Laboratory, Cambridge

Bayesian inference methods are widely used to analyse observations in astrophysics and cosmology, but they can be extremely computationally demanding. Recent work in this area by the Cavendish Astrophysics Group has focussed on developing new methods for greatly accelerating such analyses, by up to a factor a million, using neural networks and nested sampling methods, such as the SkyNet and MultiNest packages respectively. These have recently been combined into the BAMBI algorithm, which accelerates Bayesian inference still further. I will give an outline of these approaches, which are generic in nature, and illustrate their use in a cosmological case study.

Bayesian hierarchical models for supernova cosmology

Roberto Trotta (Imperial College)

Supernovae type Ia (SNIa) are standardazible candles that can be used to determine distances in the Universe and hence to learn about the expansion history of the cosmos, as well as to detect and characterize dark energy.

In this talk I will present recent advances in determining distances for SNIa and in inferences on cosmological parameters thanks to Bayesian hierarchical models, that allow one to include in a principled statistical way all sources of uncertainty (measurement error, population-level distributions, dust extinction, etc). I will demonstrate how these new methods outperform the standard approach in the vast majority of cases, leading to significantly improved cosmological constraints and smaller statistical bias.

Thursday 8 May 2008

Robust Sparse Analysis Regularization

Gabriel Peyré (CNRS and Université Paris-Dauphine)

In this talk I will detail several key properties of L1-analysis regularization for the resolution of linear inverse problems [5]. With the notable exception of [1,3], most previous theoretical works consider sparse synthesis priors where the sparsity is measured as the norm of the coefficients that synthesize the signal in a given dictionary, see for instance [3,4]. In contrast, the more general analysis regularization minimizes the L1 norm of the correlations between the signal and the atoms in the dictionary. The corresponding variational problem includes several well-known regularizations such as the discrete total variation, the fused lasso and sparse correlation with translation invariant wavelets. I will first study the variations of the solution with respect to the observations and the regularization parameter, which enables the computation of the degrees of freedom estimator. I will then give a sufficient condition to ensure that a signal is the unique solution of the analysis regularization when there is no noise in the observations. The same criterion ensures the robustness of the sparse analysis solution to a small noise in the observations. Lastly I will define a stronger condition that ensures robustness to an arbitrary bounded noise. In the special case of synthesis regularization, our contributions recover already known results [2,4], that are hence generalized to the analysis setting. I will illustrate these theoritical results on practical examples to study the robustness of the total variation, fused lasso and translation invariant wavelets regularizations. (This is a joint work with S. Vaiter, C. Dossal, J. Fadili)

Bibliography:

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[4] J.A. Tropp. Just relax: Convex programming methods for identifying sparse signals in noise. IEEE Transactions on Information Theory, 52 (3):1030–1051, 2006.
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Implications of a new sampling theorem for sparse signal reconstruction on the sphere

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Sampling theorems on the sphere state that all the information of a continuous band-limited signal may be contained in a discrete set of samples. For an equiangular sampling of the sphere, the Driscoll & Healy (DH) sampling theorem has become the standard, requiring approximately 4L^2 samples on the sphere to represent exactly a signal band-limited in its spherical harmonic decomposition at L. Recently, we have developed a new sampling theorem on an equiangular grid (hereafter the MW sampling theorem), requiring only 2L^2 samples to represent exactly a band-limited signal, thereby redefining Nyquist rate sampling on the sphere. The MW new sampling theorem has important implications for sparse signal reconstruction from incomplete data. Indeed, considering a large class of sparsity dictionaries with atoms positioned on each grid point through a convolution process, the dimension of the dictionary depends on that of the grid. This is typically the case for the decomposition of signals in the Dirac basis or in a wavelet frame. In this context, signal sparsity naturally increases proportionally to the grid dimension. The argument can also be extended to sparsity in the gradient. The dimensionality of the problem also increases proportionally to the grid dimension if the signal is recovered in real space or in the sparsity dictionary. A reduction in the grid dimension between the DH and MW sampling schemes thus improves both the sparsity and dimensionality of the signal, which, as described by the theory of compressive sampling, improves the quality of reconstruction through sparsity-promoting algorithms. We illustrate the implications of the MW sampling theorem for sparse signal reconstruction with an inpainting problem.

Dictionary Learning and Astronomical Image Restoration

Simon Beckouche (CEA)

State of the art denoising algorithms that use fixed basis like wavelets or curvelets have shown some limitations when processing images containing complexe texture features. We propose to use recently developed dictionary learning techniques to overcome those limitations. We address here the problem where a white gaussian noise is to be removed from an image. The original image is assumed to be sparsly represented in a dictionary which is learned during the denoising. Patch averaging has proven to be an efficient way to combine local sparsity constrain and a global Bayesian treatment and is applied here to process astrophysical image compared to classic wavelet shrinkage and associated techniques.

Bayesian and Frequentist approaches

Joguesh Babu (PSU)

Though the Bayesian vs. Frequentist debate is largely muted in statistics community, it still goes on among those applying these in Physical Sciences. The debate often misses some salient features on both sides, and relay on simplistic arguments based on single aspect of the methodology such as p-values or priors. The discussion tries to convince that each approach has something to contribute. It is always good statistical practice to analyze the data by several methods and compare.

A Gradient-like Variational Bayesian Approoach for Unsupervised Eextended Emission Map-Making from SPIRE/HERSCHEL DATA

Thomas Rodet, Hacheme Ayasso, and Alain Abergel (Orsay University)

In this work, we study the problem of extended source emission high resolution map-making, which is tackled as an inverse problem. Therefore, an unsupervised Bayesian framework is pro- posed for estimating sky maps and all the related hyperparameters. For the forward problem, a detailed physical model is introduced to describe different instrument effects like: optical transfer function, pointing process and temperature drifts. Several models for pointing and optical transfer functions are implemented and a Gaussian distribution is attributed to noise model. Since we are interested in extended emission, a prior information accounting for smooth variations can be intro- duced. Thanks to the Bayesian approach, this information can be injected easily in a probabilistic form. A Markovian field with four closest neighbours is used as a sky prior.
In our unsupervised approach, we write the joint posterior of the sky and all the hyperparameters (prior correlation and noise parameters) as a function of the likelihood and the different priors. Nevertheless, its expression is complicated and neither the joint maximum a posteriori (JMAP) nor the posterior mean (PM) have an explicit form. Therefore, an approximation is needed. Two techniques are generally used: Stochastic, as in Markov Chain Monte Carlo sampling (MCMC) methods, and deterministic like the variational Bayesian technique (VBA). The idea of the latter is to approximate the true posterior by a free form separable distribution which minimizes the Kullback-Leibler divergence. For distributions in the exponential family, the approximating posterior has an explicit parametric form with shaping parameters which are mutually dependent. Their optimal values are achieved by separately updating them in an iterative layout.
We propose a new gradient like variational Bayesian approach to tackle the problem of posterior approximation. In order to accelerate the convergence, shaping parameters are updated simultaneously like in a gradient method. Furthermore, optimal gradient steps expressions can be calculated to minimize the Kullback-Leibler divergence.
We applied our approach for unsupervised map-making of simulated data and real SPIRE/Herschel data. The results for simulated data show good performance for our method in term of reconstruction quality and hyperparameters estimation. The gain in spatial resolution is a factor of three compared to conventional methods all while keeping low residual noise level. Indeed, application to real data form SPIRE instrument confirms this gain. Moreover, reconstructed maps have less artifacts due to temperature drifts. We present several spectacular maps from the Orion Bar, the Polaris flare and the Horsehead nebula made by our method and compare them to maps provided by the Herschel official map-making tool.
Keywords: Super-resolution, Bayesian methods, SPIRE, Herschel, Variational Bayesian

Global strategy for spectral inversion from a model library

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In the framework of the Gaia mission, we developed and we tested different methods for the spectral inversion, i.e. the determination of the atmospheric parameters for the observed stellar spectra. These methods are based on statistical fittings taking into account a model library. We propose a global strategy allowing us to get very efficiently measurements with the best quality. This strategy is based on the following phases:
1. Reduction of spectra dimension with a selection of the principal components. A compression by a factor 25 was applied.

2. Identification of the closest spectrum in the model library using an oblique and balanced decision tree. This tool assumes the identification with a computational time proportional to log(N), if N is the number of models in the library.
3. Refinement of the parameter estimations using a classical Gauss-Newton algorithm. Taking into account the previous phase, the number of steps is reduced, in comparison to the application of this algorithm without any prior knowledge. The convergence to the global minimum of the Euclidian distance is also quite always assumed.
4. A Bayesian correction, based on the Nadaraya-Watson formula allows the reduction of the biases. In this phase, the posterior expectation of the parameters is estimated for the previous determination. The conditional PDF is determined from training on the whole library with an added noise.

Tests on simulated Gaia RVS spectra will be analyzed. The question of the best sampling of the model library will be discussed in the conclusion.

Inverse Problems with Poisson Noise: a Sparsity and Optimization Tour

Jalal Fadili (Caen University)

In many acquisition devices, and particularly in astronomical imaging, the noise stems from fluctuations of a counting process (e.g. photodetectors in cameras, etc.). In such a case, the Poisson distribution is an appropriate noise model, and the goal is to estimate the intensity of such a process. However the major difficulty is that the variance of the Poisson noise is equal to its mean. While the Poisson noise removal problem has received considerable interest in the literature with a host of estimation methods, the problem becomes more challenging when the underlying intensity undergoes the action of a bounded linear operator that entails degradation or loss of information, e.g. convolution with an optical device PSF. Estimating the intensity profile in this case is an ill-posed inverse problem.

In this talk, I will give some essential ingredients on how to solve linear inverse problems with Poisson noise by exploiting ingredients originating from variational analysis, sparse regularization and non-smooth convex optimization. More precisely, a proper data fidelity term is constructed to reflect the statistics of the noise. On the other hand, the regularization is formed through different terms reflecting a priori knowledge on the objects to be reconstructed. The
solution to the inverse problem is then cast as the minimization of a composite non-smooth convex objective functional and solved using what is now known as proximal splitting algorithms. Experimental results on deconvolution and inpainting will be reported to illustrate the wide applicability of the framework.

MAP-based sparse detection strategies. Application to the hyperspectral data of the MUSE instrument

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The ESO VLT instrument MUSE (Multi-Unit Spectroscopic Explorer) is a second generation integral field spectrograph, which will provide a huge quantity of hyper-spectral data composed by cubes of 300×300 spectra sampled at ≈ 4000 wavelengths of the visible spectrum. The expected performances of MUSE should

allow the detection of very distant galaxies, seen at more than 10 billions light-years distance. One of the challenging scientific objectives is then the detection and the characterization of extremely faint and tiny astrophysical sources. Such light sources are spatially localized within very few pixels and may show only a few spectrally salient features. The processing of such data therefore poses important challenges. First, the data will be acquired at very low signal-to-noise ratio with a highly variable noise level, which strongly depends on the spectral and spatial coordinates in the data cube. Second, the size of the data calls for estimation and detection methods that cannot be arbitrarily complex.
In this context, we have proposed in recent works efficient and reliable detection techniques for the analysis of MUSE data based on the use of composite hypothesis tests, which are adapted to sparse signals through the use of Maximum A Posteriori (MAP) estimates. Methods based on sparse representations are indeed particularly appropriate for such data as they operate a reduction of the dimension, while preserving accurate data modeling. The two detection tests we have considered are the Posterior Density Ratio (PDR, introduced by Basu in 1996 1 but not in the context of sparse signals) and the MAP-based Likelihood Ratio (LRMAP) tests, which showed better performances than classical tests (i.e. Generalized Likelihood Ratio Test and Bayes Factor) for hyperspectral data. PDR and LRMAP detection tests are in this case set up in order to take advantage of a specific redundant dictionary, especially designed for MUSE spectra in accordance with astrophysical knowledge.
After summarizing the theoretical properties of the considered sparse detection tests, we turn to detection strategies that take into account not only the spectral but also the spatial dependencies that exist between neighbor spectra in the data cube. This approach implements a cascade of appropriate detection tests. In this contribution, we propose an analysis of the resulting global False Alarm rate (FA) for each given spectra, through the use of FA-maps. Numerical comparisons are presented on simulated data cubes provided by the MUSE consortium.

Source separation for high quality CMB estimation

Jerome Bobin (CEA)

After a series of successful full-sky CMB (Cosmic Microwave Background) experiments (COBE and WMAP), the latest spatial mission of the European Space Agency, Planck, has started observing the whole sky in mid-2009. This experiment is of premier importance for the cosmologists to study the birth of our universe via the analysis of the CMB. The latter astrophysical component, among others, is not directly observable in the Planck data but rather mixed up with other components. For the sake of scientific exploitation, accessing such precious physical information requires extracting several different astrophysical components (CMB, Sunyaev-Zel'dovich clusters, galactic foregrounds). Mathematically, this problem amounts to a component separation problem. In the field of CMB studies, a very large range of source separation methods have been applied. Most of these methods assume that the sought after components are mixed up in the data according to the standard global linear mixture model. Nevertheless, this model is not accurate and more accurate models require modeling the mixtures locally to estimate the CMB map with high quality. In this talk we will introduce a new sparsity source separation coined L-GMCA which allows for a local modeling the components mixtures using sparse multiscale signal representations. We will show numerical results on realistic Planck simulated data showing the ability of the proposed method to estimate the CMB with high precision.

Wednesday 16 May 2012

The ALFALFA Census of Gas-Bearing Galaxies at z=0

Martha Haynes
Cornell University

Capitalizing on the huge collecting area of the Arecibo telescope and the survey capability of the 7-beam Arecibo L-band Feed Array (ALFA), the Arecibo Legacy Fast ALFA (ALFALFA) extragalactic HI 21cm line survey aims to produce a census of HI bearing objects found over 7000 square degrees of the high galactic latitude sky out to $z < 0.06$. The survey observations are 96% complete and a catalog is available for about 50% of the final survey area. Its processing pipeline integrates access to public extragalactic datasets to allow identification of coincident multiwavelength counterparts. I will review the nature of the ALFALFA population in comparison with that included in the SDSS within the same volume and discuss some of its more enigmatic HI sources, including "dark galaxy" candidates, possible very low mass "mini-halos" in the Local Group and serendipitously detected OH megamasers at $0.16 < z < 0.25$. Most surprisingly, ALFALFA detects many more high HI mass objects than predicted by previous estimates of the HI mass function, a result of particular importance since it directly impacts, in a positive sense, estimates of the expected HI detection rate at high z with the SKA and its pathfinders.

The Cornell Atlas of Spitzer Spectra and the recent advances in the extraction of complex sources

Vianney Lebouteiller (CEA Saclay, France), D.J. Barry, H.W.W. Spoon, G.C. Sloan, D.W Weedman, J.R. Houck (Cornell University, USA)

While the Spitzer Space Telescope ended its cold mission, the effort and expertise on the data reduction and analysis reached its maximum potential soon after. I will present two different aspects of the data treatment, by showing (1) how spectra can be reduced and analyzed in a systematic way that accounts for all the observational hazards, and (2) how observations of the most complex sources - often disregarded because of their complexity and despite their uniqueness - can now be tackled.

In a first part, I will present the Cornell Atlas of Spitzer/IRS Spectra (CASSIS; Lebouteiller et al. 2011), which gathers the spectra of more than 15 000 observations performed with the IRS instrument (5-40um, R~120) on board Spitzer. The spectra are provided to the community with a special emphasis on a synergy between Spitzer spectra and other IR missions.
CASSIS benefits from the recent advances allowed by the AdOpt algorithm (Lebouteiller et al. 2010) within the SMART environment (Higdon et al. 2004). AdOpt is the first algorithm to create and to use a super-sampled point-spread function (PSF) to perform an optimal extraction for the IRS data. The super-sampled PSF is key to extractions anywhere along the aperture, especially in cases when the spectral trace is undersampled by the detector. Thanks to the AdOpt algorithm, CASSIS is a versatile pipeline that reaches the best signal-to-noise ratio to date. Essential steps in the public release of the spectra are now made possible, such as an automatic choice for the background subtraction determined from the identification and characterization of possible contaminating sources.
Although presented as an atlas, CASSIS was mainly developed as a tool for massive data analysis. Spectra are converted into SQL tables that can be queried for a wide range of applications ranging from the comparison spectra/spectra (or spectra/models) to the automated measurement of spectral features. We thus provide a remote access to the database via dedicated servers, combined with tailored scripts. I will present the first applications, focussing on the determination of redshifts for the extragalactic sources whose identification in NED is not unique.

In a second part, I will present how the most complex sources ever observed by the IRS instrument can be handled. AdOpt is the only tool able to extract the complex sources, i.e., partially-extended sources and/or blended sources and/or sources with complex (spatially varying) background emission. I will show how the algorithm, using a multiple linear regression, simultaneously accounts for the presence of multiple sources with a background emission. Finally, I will present the most recent update which allows modifying the PSF profile to mimic a partially-extended source.

Automatic Identification of Faults in Radio Astronomical Surveys

Dina Said, Russ Taylor, and Ken Barker
University of Calgary, Calgary, Alberta, Canada

The astronomical data pipeline is the process of mapping radio signals to astronomical surveys (images) that represent specific regions in the sky. The final stage of the data pipeline process is inspect the produced surveys to identify any faults that may exist. These faults may occur for any of the following reasons: (i) sensor failure during the scanning process, or (ii) mistakes in the pipeline process. Detecting these faults manually by visual inspection is a time consuming process because the survey contains approximately 8,000 channels (frequencies). Thus astronomers must inspect an average image that represents all images in different frequencies or the task is simply infeasible. Furthermore, this technique leads to an incomplete inspection process because some faults may occur in few frequencies but do not appear in the average image. This paper investigates conducting an automatic inspection of radio astronomical surveys using various image processing techniques. The automation process will dramatically reduce the amount of time and effort astronomers invest to manually verify the quality of astronomical surveys.

Unsupervised Photometric Membership Assignment in Stellar Clusters

Alberto Krone-Martins, A. Moitinho de Almeida
SIM/FC Universidade de Lisboa

One of the most ancient problems in the photometric study of stellar clusters is the assignment of membership for its stars. Although several approaches exist for attacking this problem, they usually involve the adoption of complex theoretical models for the photometric data (isochrones) and/or the selection and use of control fields, possibly biasing some results.

We have developed a data-driven, fully automated and unsupervised method to perform membership assignment in Stellar Clusters using photometric and spatial data, which is independent from complex theoretical models, as well as from the adoption of observational control fields. Our method is based on an iterative solution, and relies on Principal Component Analysis, clustering algorithms and kernel density estimations. Optionally, it also allows the user to take into account error models and missing data. We will present a description of the method, results obtained with its application to a set of realistic simulations as well as results obtained from analysis of real data of selected Open Clusters.

Detection of polarization effects in Gaia data

Frederic Raison (ESAC/ESA Madrid, Spain)

The Gaia satellite will observe about one billion stars and other point-like sources. The astrometric core solution will determine the astrometric parameters (position, parallax, and proper motion) for a subset of these sources, using a global solution approach which must also include a large number of parameters for the satellite attitude and optical instrument. The quality of the astrometric solution will depend on the validity of the instrument model.

Optical simulations have showed that Gaia mirrors will be sensitive to light polarization because of their coating properties. This sensitivity results in a shift of the source image on the Gaia detectors, depending on its polarization. These micro-arsecond shifts can be in the order of magnitude of the expected accuracy of the instrument.

Our simulations have showed that the global solution can be improved by including into the global solution approach additional parameters related to the apparent polarization of the sources. We discuss the possibility of deriving the apparent source polarization degree and angle from the global solution approach. Finally, some possible applications will be presented.

Revealing long term features on synoptic maps of the Sun corona

Antoine Llebaria, P.Lamy (LAM, Marseilles)

Synoptic maps of the solar corona are useful tools in order to study the evolution of coronal activity for long periods of time (years). They show the coronal activity as function of time. This activity is measured as brightness in a circular profile around the solar disk as function of the latitude. The time series of these profiles form the synoptic maps. There are three conspicuous types of events on solar corona and therefore on synoptic maps: 1) the coronal mass ejections (CMEs), 2) the streamers 3) the coronal holes. Because all these structures are optically thin there add their brightness in the synoptic map. Streamers and coronal holes define the medium term appearance of the solar corona. CMEs are frequent and very strong transients (in general). In this paper we show how to disentangle these additive components of very diverse appearance: CME appear as temporal transients, streamers appear as wandering traces and coronal holes appear as low level smooth regions. Median filtering is efficient for transients, thresholding and morphologic analysis is good for coronal holes but the existence of multiple streamers need a combined approach to disentangle these components using Hough transform techniques and nonlinear multiresolution analysis.

Reconstructing the non shift-invariant non-axisymmetric evolving PSF of the SODISM telescope onboard the PICARD space mission

J.-F. Hochedezet al

The PICARD space mission was launched in June 2010. Onboard its payload, the SODISM instrument has been designed to perform metrology of the photospheric and chromospheric limb of the Sun in five relatively narrow spectral passbands. To achieve this major scientific objectives, several design features were implemented. Unfortunately, after few months of operations, it became obvious that the solar images became blurry. I will explain the efforts carried out to overcome the difficulty and describe the current level of success in this endeavor.

Thursday 17 May 2012

Re-capturing cosmic information in large-scale structure

Masahiro Takada

Large-scale structure (LSS) probes such as galaxy clustering and weak lensing are very powerful probe of cosmology. In particular, combining LSS probes with cosmic microwave background (CMB) allows us to trace time evolution of structure formation over the cosmic age, which enables to improve cosmological constraints as well as to test gravity on cosmological scales. However, the LSS fields are affected by nonlinear clustering, and are non-Gaussian by nature. Hence the conventionally used two-point correlation function methods cannot extract the full information from the LSS fields, unlike in the CMB. To extract the non-Gaussian information that cannot be picked up by the two-point correlation function, we need to use the higher-order statistics or use topological quantities such as the Minkowski functionals. Which statistical quantities are most optimal to extract the non-Gaussian information is an open issue. In this talk, I will review non-Gaussian issues in LSS, and then discuss which method can be useful. These issues are relevant for upcoming massive galaxy surveys such as DES, Subaru HSC/PFS surveys, Euclid and LSST.

A compressed sensing approach to 3D weak lensing

Adrienne Leonard (CEA Saclay), François-Xavier Dupé (LIF, University of Marseille), Jean-Luc Starck (CEA Saclay)

Weak gravitational lensing is an ideal probe of the dark universe. In recent years, several linear methods have been developed to reconstruct the density distribution in the Universe in three dimensions, making use of photometric redshift information to determine the radial distribution of lensed sources. We aim to address three key problems seen in these methods; namely, the bias in the redshifts of detected objects, the line-of-sight smearing seen in reconstructions, and the damping of the amplitude of the reconstruction relative to the underlying density. We also aim to detect structures at higher redshifts than have previously been achieved, and to improve the line-of-sight resolution of our reconstructions. We consider the problem under the framework of compressed sensing (CS). Under the assumption that the data are sparse or compressible in an appropriate dictionary, we construct a robust estimator and employ state-of-the-art convex optimisation methods to reconstruct the density contrast. We demonstrate that our method is able to accurately reproduce cluster haloes up to a redshift of $z = 1.0$, deeper than state-of-the-art linear methods. We directly compare our method with these linear methods, and demonstrate minimal radial smearing and redshift bias in our reconstructions, as well as a reduced damping of the reconstruction amplitude as compared to the linear methods. In addition, the CS framework allows us to consider an underdetermined inverse problem, thereby allowing us to reconstruct the density contrast at finer resolution than the input data.

Bayesian constraints on dark matter halo properties using gravitationally-lensed supernovae

Natallia Karpenka (Stockholm), Farhan Feroz (Cambridge), Michael Hobson (Cambridge)

A hierarchical Bayesian method is presented for the analysis of Type-IA supernovae (SNIa) observations to constrain the properties of the dark matter haloes of galaxies along the SNIa lines-of-sight via their gravitational lensing effect. The full joint posterior distribution of the dark matter halo parameters is explored using the nested sampling algorithm {\sc MultiNest}, which also efficiently calculates the Bayesian evidence, thereby facilitating robust model comparisons. We demonstrate the capabilities of the method by applying it to realistic simulated SNIa data, based on the real 3-year data release from the Supernova Legacy Survey (SNLS). For these simulations, we obtain robust and accurate parameter constraints and model selection results for two halo models: a truncated singular isothermal sphere (SIS) and a Navarro--Frenk--White (NFW) profile. In the analysis of the real SNLS data, however, we obtain only very weak constraints on the halo parameters, which are consistent with no lensing signal. The Bayesian evidence also prefers the no-lensing model to both the truncated SIS and NFW halo models for both conservative and restrictive priors on the halo parameters.

Tomographic detection of the ISW signal

François-Xavier Dupé (Aix-Marseille Université), Anaïs Rassat (EPFL), Jean-Luc Starck (CEA)

One of the main challenges of modern cosmology is to understand the nature of the mysterious dark energy that causes the cosmic acceleration. The integrated Sachs-

Wolfe (ISW) effect is sensitive to dark energy, and if detected in a universe where modified gravity and curvature are excluded, presents an independent signature of dark energy. The ISW effect occurs on large scales where cosmic variance is high and where owing to the Galactic confusion we lack large amounts of data in the CMB as well as large-scale structure. In the continuation of previous works, we propose an extension of the Saclay for a tomographic study of the ISW signal as such study will be relevant with the incoming Euclid mission. This method assumes only that the CMB field is Gaussian. It is based on a sparse inpainting method to reconstruct missing data and uses a bootstrap or Monte-Carlo technique to avoid assumptions about the statistics of the estimator. It is a complete method, which uses three complementary statistical methods respectively based on correlation detection with multiple testing, model selection with generalized likelihood ratio and amplitude estimation of the ISW signal with a test of its nullity. We apply our method to Euclid like simulations and show we can expect at least a 5σ model-independent detection of the ISW signal with WMAP7-like data, even when considering missing data. We also find that detection levels are independent from whether the galaxy field is normally or lognormally distributed.

Back to normal - Box-Cox transformations in cosmology

Benjamin Joachimi (IfA, Edinburgh), Andy Taylor (IfA, Edinburgh), Alina Kiessling (IfA, Edinburgh; JPL)

In this talk I am going to present recent results on cosmological applications of Box-Cox transformations, a widely used Gaussianisation tool that has, up to now, received little attention in astrophysics. We have applied Box-Cox transformations to the weak lensing projected mass distribution to generalise investigations of the currently popular logarithmic transformations, being the first to determine cosmological constraints from the transformed observables. Our work demonstrates that Box-Cox transformations outperform logarithmic transformations in terms of Gaussianisation, but I will show and illustrate that both fail to yield stronger constraints on cosmology in the presence of realistic noise levels. Furthermore I am going to highlight recent work on the generalisation of Fisher matrices by means of Box-Cox transformations in order to produce predictions of arbitrary posterior distributions. Finally, I will outline how Box-Cox transformations can be used to construct, to good approximation, statistically independent parameters for arbitrary problems of parameter inference.

References:

Joachimi, Taylor & Kiessling (2011), MNRAS, 418, 145
Joachimi & Taylor (2011), MNRAS, 416, 1010

Model-dependent covariance matrix for the study of Baryon Acoustic Oscillations

Antoine Labatie (CEA Saclay), Jean-Luc Starck (CEA Saclay), Marc Lachièze-Rey (APC, Paris 7)

Baryon Acoustic Oscillations (BAO) are a feature imprinted in large-scale structures of the Universe by acoustic waves traveling in the hot plasma before recombination. BAO detection at the expected scale (≈150 Mpc) strongly supports current cosmological models with a nearly linear evolution from redshift z ≈ 1000 and the existence of dark energy. Besides, BAOs provide a standard ruler which enable to constrain cosmological parameters.

In this work, we focus on the study of BAOs using the correlation function measurement. We first present the classical method for BAO detection based on the difference of chi-square between the 2 hypotheses H_0 (no-BAO) and H_1 (BAO).

Next we present the classical likelihood analysis for constraining cosmological parameters using the BAO feature in the correlation function.
Both procedures make the simplification that the measured correlation function has a constant covariance matrix, instead of a model-dependent covariance matrix. We first use lognormal simulations to test the effect of a simple model-dependence of the covariance matrix. We find that the classical method for BAO detection can give very wrong estimates of the significance in this case. We also find that constraints on cosmological parameters are significantly different from the ones obtained with a constant covariance matrix.
Finally we work on the Luminous Red Galaxies sample of the Sloan Digital Sky Survey Data Release 7, with a model-dependent covariance matrix that is computed using a lot of lognormal simulations. We test the effect of this model-dependence both on the BAO detection and on cosmological parameter constraints. Our goal is to see how important it is to take into account this model-dependence in future BAO studies.

Systematic Trends In Sloan Digital Sky Survey Photometric Data

D.M. Bramich (ESO) & W. Freudling (ESO)

We investigate the Sloan Digital Sky Survey (SDSS) photometry from Data Release 8 (DR8) in the search for systematic trends that still exist after the calibration effort of Padmanabhan et al. 2008. We consider both the aperture and point-spread function (PSF) magnitude measurements in the DR8 data base. Using the set of objects with repeat observations, we find that a large proportion of the aperture magnitude measurements suffer a ~0.2-2% level systematic trend as a function of PSF full width half-maximum (FWHM), the amplitude of which increases for fainter objects. Similar analysis of the PSF magnitude measurements reveals more complicated but similar amplitude systematic trends as a function of PSF FWHM and object brightness. We suspect that sky over-subtraction is the cause of the largest amplitude trends as a function of PSF FWHM. In addition, we detect systematic trends as a function of subpixel coordinates for the PSF magnitudes which are of peak-to-peak amplitude of ~1.6 mag and ~4-7 mag for the sub- and super critically sampled images, respectively. We note that the systematic trends that we detect are similar in amplitude to the reported ~1% and ~2% precision of the SDSS photometry in the griz and u wavebands, respectively, and therefore their correction has the potential to substantially improve the SDSS photometric precision. We provide an IDL program specifically for this purpose.
Finally, we note that the SDSS aperture and PSF magnitude scales are related by a non-linear transformation that departs from a linear relation by ~1-4%, which, without correction, invalidates the application of a photometric calibration model derived from the aperture magnitudes to the PSF magnitudes, as has been done for SDSS DR8.

Interdisciplinary Science in Astronomy: A review

Pavlos Protopapas (Harvard)

Are we ready to let machines do the work so we can now concentrate on the science questions ? Have we reached the point where statistical and machine learning methods have become useful tools rather than a nuisance and the practice of the few ? I will present four examples where significant progress has been made and the interdisciplinary practices have brought fruitful results. These include, automatic classification, Bayesian parameter inferences, event detection and anomaly detection, and design of surveys and follow ups.

False Alarm Probability for periodogram peaks based on bootstrap and extreme-value techniques

Maria Süveges (ISDC Data Centre for Astrophysics, Geneva University)

One of the most pertinent problems in spectral analysis of astronomical time series is the assessment of significance of periodogram peaks. The origin of many difficulties is the need for a noise level estimate before the separation of the time series into signal and noise, the unclear meaning of the number of independent frequencies and the manner how it should be taken into account. I propose to avoid these problems by a bootstrap of the original time series, which makes the procedure independent of the distributional characteristics and the level of the noise, and by the application of univariate extreme-value methods. Generalized extreme-value distributions are used as general limiting distributions for maxima; they depend only on the decay of the right tail of the underlying distribution, but not on its precise form. Moreover, there is no need to compute the complete oversampled frequency range for each bootstrap repetition: under the zero hypothesis of the observed time series being a pure noise, the maxima of only a part of the spectra of the repetitions are sufficient to estimate the False Alarm Probability for the observed original peak. The method is tested on time series of variable stars from the Stripe 82 data of the Sloan Digital Sky Survey.

Evidence of Chaotic Dynamics in Gamma Ray Burst Explosions

G. Greco (1), C. Bartolini (2), R. Bedogni (1), G. Beskin (3), A. Guarnieri (2), S. Karpov (3) R. Rosa (4)
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(3) Special Astrophysical Observatory of Russia Academy of Science, Russia
(4) Department of Statistical Science, University of Bologna, Italy

Prompt γ-ray emissions from gamma-ray bursts (GRBs) exhibit a vast range of extremely complex temporal structures with a typical variability time-scale significantly short – as fast as milliseconds. This work aims to investigate the apparent randomness of the GRB time profiles making extensive use of linear/nonlinear techniques combining the advanced spectral method of the Singular Spectrum Analysis (SSA) with the classical tools provided by the Chaos Theory. Despite their morphological complexity, we detect evidence of a non stochastic short-term variability during the overall burst duration – seemingly consistent with a chaotic behavior. The phase space portrait of such variability shows the existence of a well-defined strange attractor underlying the erratic prompt emission structures. We will show that the use of the advanced spectral method of the SSA, together with the classical tools provided for in the Theory of Chaos, proved largely successful in the analysis of the complex morphological structure of the prompt emissions from GRBs.

Ref: http://www.nature.com/srep/2011/110914/srep00091/full/srep00091.html

Blind searches for gamma-ray pulsars with Fermi LAT and Einstein@Home

Holger J. Pletsch (Max Planck Institute for Gravitational Physics, Hannover, Germany)

For the first time, the Fermi Large Area Telescope (LAT) has enabled to probe the theorized, large population of "radio-quiet" gamma-ray pulsars. These objects canonly be found through blind searches for pulsations directly in the LAT data, which represents a computing intensive problem. Exploiting a novel, efficient data-analysis method, originally developed for detecting continuous gravitational waves from fast spinning neutron stars, has allowed us to discover many new pulsars in the LAT data. This presentation will describe the new search technique and the discoveries made. In addition, it will be discussed how the volunteer distributed computing project Einstein@Home with more than a quarter-million participants is now used to enlarge the computational power for this blind survey. Prospects for further discoveries based on the combination of these advances will be elucidated.

Sparse methods for improving gravitational wave detection

Ra Inta (The Australian National University)

The most promising sources of gravitational waves expected to be detectable in the near future are sparse in four main sensing representations. Firstly, transient ('burst') sources would appear as isolated pulses in the time domain, while quasi-monochromatic ('continuous wave'; CW) signals appear as a small number of non-stationary spectral lines in the Fourier domain. The early (stationary phase) inspire portion of an unstable close compact binary ('CBC') system is expected to have a compact expression in the time-frequency ('chirp') plane. Finally the so-called 'stochastic background' is sparse in an inter-detector cross-correlation space in the Fourier domain. Here I present an overview of how the sparse nature of these signals might be exploited, in order to improve prospects of detection. I illustrate this with two case studies. The first involves a possible reduction in the computational complexity of many CW searches, by making use of a recently developed Sparse Fast Fourier Transform, with a corresponding decrease in run-time proportional to the sparsity of the signal. Because the computational bound is so prohibitive for many CW searches such an improvement will increase the number of viable targets for a given detector sensitivity. The second is an illustration of a potential improvement in the spatial position reconstruction of gravitational wave burst events, via an application of compressive sampling. Chirp template mismatch, as a result of aliasing in the time-frequency plane, leads to corresponding signal-to-noise degradation. By potentially reducing the impact of aliasing, the event may be better localised in the time-frequency plane, leading to better position reconstruction, given a network of detectors. Such an improvement would be of especially great benefit in a multi-messenger context.

Friday 18 May 2012

CMB, from Gamow to Planck

Francois Bouchet (IAP)

I will recall that the CMB is a gold mine for cosmology, which already has a long and successful history, which I will overview. I will then review the current state of knowledge, and discuss what the Planck project hopes to bring in that context. I may conclude with some thoughts on the after-Planck.

True CMB Power Spectrum Estimation

Paniez Paykari (CEA)

The cosmic microwave background (CMB) power spectrum is a powerful cosmological probe as it entails almost all the statistical information of the CMB perturbations. Having access to only one sky, the CMB power spectrum measured by our experiments is only a realization of the true underlying angular power spectrum. In this paper we aim to recover the true underlying CMB power spectrum from the one realization that we have without a need to know the cosmological parameters. The sparsity of the CMB power spectrum is first investigated in two dictionaries; Discrete Cosine Transform (DCT) and Wavelet Transform (WT). The CMB power spectrum can be recovered with only a few percentage of the coefficients in both of these dictionaries and hence is very compressible in these dictionaries. study the performance of these dictionaries in smoothing a set of simulated power spectra. Based on this, we develop a technique that estimates the true underlying CMB power spectrum from data, i.e. without a need to know the cosmological parameters. This smooth estimated spectrum can be used to simulate CMB maps with similar properties to the true CMB simulations with the correct cosmological parameters. This allows us to make Monte Carlo simulations in a given project, without having to know the cosmological parameters. The developed IDL code, **TOUSI**, for Theoretical pOwer spectrUm using Sparse estImation, will be released with the next version of **iSAP** software.

Reconstructing the CMB lensing on PLANCK-like temperature maps

Laurence Perotto (LPSC), S. Plaszczynski (LAL), J.-L Starck (CEA)

The gravitational weak lensing of the cosmic microwave background (CMB) by the line-of-sight matter provides a unique probe of the gravitational potential at large scales and intermediate redshifts. It induces non-gaussianity within the CMB anisotropy maps, which allows the reconstruction of the lensing potential through four-point function estimates. When this reconstruction is performed on PLANCK-like data, it yields a nice measurement of the lensing potential power spectrum, providing one deals with the various systematics among which the most prominent are the astrophysical foreground residuals -- including point sources -- and inhomogeneous noise. We propose two different methods of lensing extraction targeted to PLANCK-like temperature maps. The first one consists in applying a full-sky minimum-variance quadratic estimator on the CMB map after a foreground cleaning with a component separation algorithm and a data restoration of the most contaminated region of the sky using a sparse inpainting procedure. Extensive tests on PLANCK-like maps, has been proved this method to provide a robust lensing reconstruction showing a small residual bias which can be corrected by a Monte-Carlo afterwards. We developed a complementary approach devoted to apply on maps from an unique frequency channel without having recourse to any component separation, which requires to deal with severe spatial cuts of the maps. We show that the best strategy consists in adopting an hybrid approach: the largest scales are still reconstructed through a full-sky estimator on maps restored by inpainting whereas the small scales are better measured locally using a flat-sky estimator on local overlapping tangent planes extracted from the masked sky. This local method relies on original solutions to solve the issues related to the sphere-to-plane projection.

After a brief review of the CMB lensing, I will detail these two proposed approaches, highlighting the adopted solutions to deal with the systematics and present how they perform when applied on realistic PLANCK-like simulations, then I will open a discussion on their respective merits.

Multi-resolution internal template cleaning: An application to the CMB polarization data

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Cosmic microwave background (CMB) radiation data obtained by different experiments contain, besides the desired signal, a superposition of microwave sky contributions. We present a fast and robust method (Fernández-Cobos et al., 2012), using a wavelet decomposition on the sphere (Casaponsa et al., 2010), to recover the CMB signal from microwave maps. The decomposition is implemented as part of a fully internal template fitting method, minimizing the variance of the resulting map at each scale. An application to WMAP polarization data is presented, showing its good performance particularly in very polluted regions of the sky. Using a chi^2 characterization of the noise, we find that the residuals of the cleaned maps are compatible with those expected from the instrumental noise. The E-mode power spectrum C_{\ell}^{EE} and the cross power spectrum C_l^{TE} are calculated. We detect the E-mode acoustic peak at l around 400, as predicted by the standard Lambda CDM model. The B-mode power spectrum C_l^{BB}$ is compatible with zero. Another application is developed with simulations of polarization data obtained by a *QUIJOTE*-like experiment (Rubiño-Martín, 2010). The aim of this exercise is to check if this procedure is useful for detecting a B-mode signal with r=0.1 taking into account realistic instrumental conditions.

References:

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Compact Sources Removal for Full-Sky CMB Data using Sparsity

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Bright point source emissions contaminate full-sky CMB data over a significant fraction of the sky. Their spectral variability makes difficult to blindly separate them from other emissions, even using the recent localized source separation techniques. Residual point sources therefore affect the subsequent CMB / foregrounds analyses, and a dedicated processing is required to clean the maps from these emissions, either prior to source separation or in the CMB restored maps.

The brightest sources can typically be masked and inpainted prior to CMB analysis (e.g. [1-3]). Indeed it has been reported that inpainting does not affect significantly the lensed signal [3], gaussianity tests [1] nor estimating the ISW [4]. However, when cleaned CMB maps are intented to be subtracted from the original data for analysis of the foregrounds, inpainting does not do a good job since it cannot recover the true underlying CMB signal in the masked regions.

We rather propose in this work a new method to subtract the brightest compact source emissions either in the original maps, or the residual point sources in the CMB final maps. This method essentially involves three steps: 1) the brightest point sources are localized in the maps according to a catalogue of detected compact sources [5], 2) the shapes of the source convolved with the beams are fitted according to elliptical gaussian models, 3) their fluxes are estimated so as to minimize the l1 norm of the spherical harmonics coefficient of the background. Results are presented on simulations obtained from the Planck Sky Model [6].

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[2] Abrial et al 2008, Statistical Methodology 5, 289-298
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[4] Dupé et al 2011, A. & A. 534, A51
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Neural network estimator to measure local non-Gaussianity in CMB

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We present a multi-class neural network (NN) classifier as a method to measure non-Gaussianity, characterised by the local non-linear coupling parameter fNL, in maps of the cosmic microwave background (CMB) radiation. The classifier is trained on simulated non-Gaussian CMB maps with a range of known fNL values by providing it with wavelet coefficients of the maps; we consider both the HealPix (HW) wavelet and the spherical Mexican hat wavelet (SMHW). When applied to simulated test maps, the NN classifier produces results in very good agreement with those obtained using standard chi2 minimization. The standard deviations of the fNL estimates for WMAP like simulations were sigma = 22 and sigma = 33 for the SMHW and the HW, respectively, which are extremely close to those obtained using classical statistical methods in Curto et al. and Casaponsa et al. Moreover, the NN classifier does not require the inversion of a large covariance matrix, thus avoiding any need to regularise the matrix when it is not directly invertible, and is considerably faster.

Extragalactic point source detection in WMAP 7-year data at 61 and 94 GHz

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The detection of point sources in Cosmic Microwave Background maps is usually based on a single-frequency approach, whereby maps at each frequency are filtered separately and the spectral information on the sources is derived combining the results at the different frequencies. On the contrary, in the case of multi-frequency detection methods, source detection and spectral information are tightly interconnected in order to increase the source detection efficiency.

In this work we apply the matched multifilter method to the detection of point sources in the WMAP 7yr data at 61 and 94 GHz. This linear filtering technique takes into account the spatial and the cross-power spectrum information at the same time using the spectral behaviour of the sources without making any a priori assumption about it. We follow a two-step approach. First, we do a blind detection of the sources. Second, we do a refined analysis at their positions to improve the signal-to-noise ratio. At 94 GHz we detect 157 5σ objects at galactic latitude |b|>5° (excluding the Large Magellanic Cloud region); 129 of them are reliable extragalactic sources and 28 are known Galactic sources or lie in regions of intense Galactic emission. From the 129 extragalactic detections, 111 of them lie outside the WMAP Point Source Catalog mask. All those 129 extragalactic detections have counterparts in lower frequency radio catalogues; 18 of them are not included in the WMAP 7yr c atalogue. Our results constitute a substantial improvement over the WMAP Five-Band Point Source Catalog, which contains 87 5σ detections at 94 GHz.

ABSTRACTS – POSTER CONTRIBUTIONS

EMphot: Photometric Software with Bayesian Priors. Application to GALEX

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EMphot is a software for the photometry of astrophysical sources, galaxies and stars, in crowded field images. Its goal is to estimate the flux in a low resolution band using prior information (position and shape) from a better resolved band, in a Bayesian approach under the Poisson noise assumption. The solution is reached with an Expectation-Maximization (EM) algorithm for msolving the photometry and includes several steps: prior shapes deblending in high resolution images, astrometry correction, PSF optimization, background correction from the residual.

Image Reconstruction with accelerated direct demodulation method for HXMT

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The hard X-ray modulation telescope mission HXMT is mainly devoted to performing an all-sky survey at 1 -- 250 keV with both high sensitivity and high spatial resolution. We propose an approach to reconstruct all-sky images using accelerated direct demodulation method (DDM) to solve the inverse problem as well as an extended demodulating-CLEAN algorithm to extract backgrounds. Our code is optimized for parallel computing and is tested on GPU computing through CUDA. Simulations are also presented in this report.

Spectral Redshift Estimation using PCA and Wavelet Denoising

D. P. Machado (CEA), A. Leonard (CEA), J.-L. Starck (CEA), and F. Abdalla (UCL)

Accurate determination of the redshifts of galaxies comes from the identification of key lines in their spectra. Large sky surveys, and the sheer volume of data they produce, has made it necessary to tackle this identification problem in an automated and reliable fashion. Current methods attempt to do this with careful modelling of the spectral lines and the continua, and/or by employing a flux/magnitude or a signal-to-noise cut to the dataset in order to obtain high S/N spectra and greater purity.

Aims. In this paper, we aim to demonstrate a new method that is automated, simple, mand largely empirical in nature. We explicitly highlight how the method performs in the very low signal-to-noise (S/N <= 3) regime.

Methods. We employ a Principal Component Analysis (PCA) technique on a template set of zero redshift, high SNR simulated galaxies, and combine it with a new, model independent method of continuum subtraction involving a wavelet filtering procedure. This is followed by a standard cross-correlation and chi^2 minimisation

procedure with a catalogue of spectra at unknown redshifts, which have similarly undergone a wavelet-based continuum subtraction procedure. Finally a wavelet denoising with a false detection rate (FDR) threshold is applied to the redshifted spectra in order to obtain clean spectra for a peak counting criterion that defines what galaxy is considered to have an accurate redshift determination.

Results/Conclusions: We show that for a simple method and selection criterion - for a spectrum to have 3 identifiable features after a FDR denoising - we can make use of an extremely low SNR catalogue, for example with a SNR = 0.5, where it is still possible to recover 65% of the redshifts with a purity of 93%, allowing us access to some data that previously would have had to have been discarded. For very large sky surveys, this recovery of redshifts for low SNR spectra, even at less optimistic levels due to the added complexity of dealing with real data, would still represent a significant boost in the number of faint, and consequently high-redshift, galaxies with accurately determined redshifts.

A wavelet-based approach to computation of weak lensing statistics

Sandrine Pires, Adrienne Leonard, Jean-Luc Starck (CEA Saclay)

Weak gravitational lensing has become a common tool to constrain the cosmological model. A prevalent tool in this regard is the aperture mass statistic. By convolving lensing maps with a filter function of a specific scale, chosen to be larger than the scale on which the noise is dominant, the lensing signal may be boosted with respect to the noise. This allows for detection of structures at increased fidelity. Higher-order statistics of the shear field, such as the skewness and kurtosis of the aperture mass statistic and peak counting, are particularly sensitive to non-Gaussianities in the weak lensing field, and can help break degeneracies which are impossible to probe using simple two-point statistics. Here, we more fully explore the formalism underlying the aperture mass statistic. We demonstrate that the aperture mass statistic is formally identical to a wavelet transform at a specific scale, and demonstrate that the wavelet formalism offers a number of advantages: large filter banks exist, allowing flexibility in optimising the statistics used, fast algorithms exist to compute the wavelet transform, and explicit denoising can be performed in the wavelet domain, which improves the constraining power of the derived statistics. We compare the constraining power of higher-order shear statistics computed under the aperture mass and wavelet frameworks (both without and with explicit denoising) by considering N-body simulations generated using 5 models along the Omega_M-sigma_8 degeneracy. We demonstrate that, in all cases, statistics computed on wavelet-denoised maps are better able to discriminate between cosmological models than either wavelet maps or aperture mass filtered maps. We further show that wavelet peak counting is the most efficient of the higher-order statistics considered here to constrain non-Gaussianities in the weak lensing field.

A novel convex optimization approach for optical interferometric imaging

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In optical interferometry, the measurable quantities are the power spectrum (magnitude of the Fourier coefficients) and the bispectrum, which provides partial phase information. Then, image recovery can be seen as a non-linear inverse problem. Traditional imaging techniques solve a regularized non-convex problem from the available data. One of the drawbacks of these methods is that their solution is highly dependent on its initialization and the particular optimization strategy. We propose to use the recently introduced phase lift technique coupled with sparsity priors to recover the measured image. In this framework, we formulate a linear inverse problem from non-linear measurements that can be solved using a convex semidefinite program. We take advantage of the versatility of convex optimization to include prior information such as signal sparsity and positivity. We demonstrate through numerical simulations the effectiveness of the convex formulation. Our preliminary results show that the proposed approach is a promising direction for optical interferometric imaging.

Markov chain Monte Carlo (MCMC) with parallel tempering to calibrate Gaia's radiation damage model.

Frederic RAISON (ESAC/ESA Madrid, Spain)

With its 106 CCD image sensors, the Gaia mission aims to create a complete and highly accurate stereoscopic map of the Milky Way. The performance of CCDs is degraded in space by the effect of solar radiation which reduces the high charge transfer efficiency through charge trapping. This effect implies for Gaia a charge loss and a centroid bias which reduce the accuracy of the measurements. A large effort has been devoted to characterize and mitigate this effect as much as possible through large ground test campaigns and simulations.

A Charge Distortion Model (CDM) is used within the Gaia community to quantify the impact of radiation on measurements. The determination of the CDM parameters from a fit to experimental data requires a global approach as the distribution of the parameters for the modeling displays many local minima. An experimental Java implementation of MCMC with parallel tempering has been developed to determine the parameters of the CDM. This tool is described and some results are presented in the case of data impacted by the trapping occurring in the CCDs serial register.

Robust Non-Negative Matrix Factorization for Multispectral Data with Sparse Priors

Jérémy RAPIN (CEA Saclay), Jérôme Bobin (CEA Saclay), Antony Larue (CEA Saclay), Jean-Luc Starck (CEA Saclay)

Recently the rapid development of multi-wavelength sensors in astrophysics has increased the need for dedicated efficient data analysis tools. Such kind of data are generally made of a collection of observations or images of the same physical phenomena in different wavelength bands. It is customary to assume that these observations are mixtures of elementary physical components which do not share the same spectrum. In the field of astrophysics, examples of these components include point sources observed by the Fermi space telescope.

In this setting, a classically used data analysis technique to extract the different

physical components of the data is blind source separation. The model is that the data is a linear mixture of these sources, i.e. Y=AS, Y being the data, S the sources and A the mixing/weight matrix. Depending on the data, several properties can be used to disambiguate the sources, such as their sparsity, and the positivity of both A (if it represents concentrations for instance) and S (which can represent an intensity). This last consideration led to Non-negative Matrix Factorization (NMF).
In this work, we compare common sparse NMF algorithms with the Generalized Morphological Component Analysis (GMCA) using positivity constraints and sparsity in the direct domain, and a more robust version of it where the priors are more precisely handled through sub-iterations, which we will call r-GMCA. We will present preliminary results showing that r-GMCA is more robust to noise contamination and large-scale problems (e.g. large number of sources).
Finally, we work on adding more complex and structured priors such as sparsity in the wavelet domain, still combined with positivity in the direct domain, in order to better identify the sources. Our goal is to show that such a prior can greatly help separating sources under fairly realistic conditions.

Spectral Characterisation of CMB Foregrounds

Tuhin Ghosh, Anthony Banday, Tess Jaffe, Clive Dickinson and Rod Davies

The study of CMB foregrounds is an important topic of research in CMB data analysis. The understanding of physics of different foreground emissions such as synchrotron, free-free and dust which dominates at microwave frequencies helps in extraction of cosmological information in much more reliable manner. In the poster, I will present spectral characterisation of foregrounds over 33 different regions of the sky. We use cross-correlation analysis to characterise the spectral properties of foregrounds which is performed in pixel space by comparing the maps of microwave sky with templates of synchrotron, free-free and dust emission, made at frequencies where the specific emission mechanism dominates. In the framework of our cross-correlation analysis, we studied some of the physical properties of foreground emission such as variation of synchrotron spectral indices, determination of free-free electron temperature and the properties of AME across the sky.

Understanding the Spectral Energy Distribution of galaxies

Viviana Acquaviva

A galaxy's Spectral Energy Distribution (SED) contains information about its physical properties, such as redshift, stellar population age, mass, star formation rate, dust content, and metallicity. These properties can be inferred via SED fitting, the procedure of comparing theoretical templates to observations to find the properties of the models that best resemble the data. This idea is simple and powerful; however, it is essential that it is implemented while avoiding biasing assumptions on the shape of the probability distribution function, and while maximizing the accuracy in the reported uncertainties. I introduce GalMC, our publicly available MCMC code for SED fitting, present the results obtained using GalMC for Lyman Alpha Emitting galaxies at $z \sim 3$ and $z \sim 2$ from the MUSYC survey, and discuss how the assumptions made in modeling the stellar populations influence our estimates of galaxy properties. Many open problems still limit our understanding of the physical nature of galaxies, and I plan to help solve some of them, hopefully with suggestions from other participants to this conference.

Automated cross-survey classifications: variable objects in LINEAR with Hipparcos training set

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In this era of large-scale astronomical surveys, abundant data provide ample material for all fields of astrophysics. This wealth requires efficient and fast methods to select appropriate samples for any specific research goal. One fundamental pre-processing step is therefore the classification of objects into classes that help this selection. We classify a set of visually selected variable sources from the Lincoln Near-Earth Asteroid Research (LINEAR) survey into well-known variability types by a supervised machine learning algorithm, Random Forest. This task was made difficult by the fact that we did not have a sufficient training set with known types observed in LINEAR, and it was necessary to use data from the Hipparcos satellite survey. The different characteristics of the two surveys introduce bias between regions occupied by the same variable types in the attribute space, unequal occurrence of types, different aliases that influence the period recovery, and bad coverage in the attribute space. We present the classification scheme, and discuss its results on the long-period variables, the Cepheids and the spot-induced variable types.