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LSST@EUROPE2

Belgrade, Serbia, June 20-24, 2016

Book of Abstracts

Editors: Željko Ivezić, Nicholas Walton
and Darko Jevremović

BELGRADE, 2016

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Text arrangement: Tanja Milovanov

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SCIENCE PROGRAMME

Mon 20 June 2016

When	What	Who	Comments
08.30	***Registration (Tea/Coffee available)***		
09.30 - 11.00	**Session 1: LSST status and overview (Chair R. Lupton)**		
09.30	Welcome		
09.45	LSST Project Status and Updates on Observing strategy	Željko Ivezić (University of Washington, USA)	
10.30	LSST Data Products	Mario Jurić (University of Washington, USA)	
11.00	*Tea/Coffee*		
11.30 - 13:00	**Session 2: Science Collaborations in the U.S. (Chair A. Vallenari)**		
11.30	LSST Science Collaborations	Lucianne Walkowicz (Adler Planetaruim, USA)	
12.00	Dark Energy Science Collaboration	Andy Connolly (University of Washington, USA)	
12.30	The role of LSST Corporation	Pat Eliason (LSSTC, USA)	
13.00-14.30	*Lunch*		
14.30 - 15.30	**Session 3: LSST Science: Dark Energy/Large-scale structure/baryon oscillations (Chair M. Jurić)**		
14.30	DE SN Surveys with LSST	Pierre Astier (LPNHE/IN2P3/CNRS, Paris, FR)	
15.00	The contribution of LSST to explore the ultra-faint surface brightness Universe	María Cebrián Renau (Instituto de Astrofísica de Canarias, ES)	
15.15	Dark Energy and galaxy clustering - how LSST will gain from the experience of VIPERS and other ESO deep spectroscopic surveys	Agnieszka Pollo (Jagiellonian University, Krakow, PL)	
15.30	*Tea/Coffee*		
16.00 - 17.30	**Session 4: LSST Science: Galaxies & poster presentation (Chair C. Mundell)**		
16.00	The critical need for PSF treatment in ultra-deep imaging of extended sources	Cristina Martinez-Lombilla (Instituto de Astrofisica de Canarias, ES)	
16.15	Low surface-brightness science using LSST: unveiling the fundamental minor-merger process	Sugata Kaviraj (University of Hertfordshire, UK)	
16:30	Poster presentation		

17:30 Conference photo

18:00 Welcome Cocktail

Tue 21 June 2016

When	What	Who	Comments
09.00 - 10.30	**Session 5: LSST Science: Active Galactic Nuclei/ Strong Lensing (Chair S. Kaviraj)**		
09.00	Active Galactic Nuclei in the LSST Era	Carole Mundell (University of Bath, UK)	
09.30	Photometric reverberation study of quasars in LSST: starlight contamination	Bozena Czerny (Center for Theoretical Physics, PL)	
09.45	Imprints of the AGN structure on time delay light curves in LSST era	Dominique Sluse (University of Liege, BE)	
10.00	Detecting sub-parsec super-massive binary black holes - LSST perspective	Luka Č. Popović (Astronomical Observatory, Belgrade, RS)	
10.15	Synergies between LSST and eROSITA	Joe Mohr (LMU-Munich, DE)	
10.30	*Tea/Coffee*		
11.00 - 12.45	**Session 6: LSST Science: Stars, Milky Way, and Local Volume (Chair N. Walton)**		
11.00	LSST and the Magellanic Clouds	Maria-Rosa Cioni (Leibniz-Institute for Astrophysics Potsdam, DE)	
11.30	LSST and E-ELT: complementary paths and intersections	Guiseppe Bono (INAF, Osservatorio Astronomico di Roma, IT)	
12.00	The fragmentation limit in the nearest stellar clusters	Nicolas Lodieu (Instituto de Astrofisica de Canarias, ES)	
12.15	The K2 RR Lyrae survey	Robert Szabo (Konkoly Observatory, MTA CSFK, HU)	
12.30	Synergies between LSST and 4MOST	Richard McMahon (University of Cambridge, UK)	
12.45	*Lunch*		
14.00 - 15.30	**Session 7A: Workshop: Local Volume, MW, Stars & Planets: L3 Requirements**		
	Led by:	Anthony Brown (University of Leiden, NL) & Janet Drew (University of Hertfordshire, UK)	
14.00 - 15.30	**Session 7B: Workshop: Cosmology & Galaxies: L3 Requirements**		
	Led by:	Joe Mohr (LMU-Munich, DE) & Richard McMahon (University of Cambridge, UK)	
15.30	*Tea/Coffee*		
16.00 - 17.30	**Session 8: Tutorial: The LSST Software Stack**		
	Led by:	Jim Bosch (Princeton University, USA) & Robert Lupton (Princeton University, USA)	

18:00 Solstice Party (Grounds of Belgrade Observatory)

Wed 22 June 2016

When	What	Who	Comments
09.00 - 09.30	**Session 9: LSST@Europe: DAC France (Chair J. Bosch)**		
09.00	The French Data Access Center	Dominique Boutigny (CNRS/IN2P3 Laboratoire d'Annecy-le-Vieux de Physique des Particules, FR)	
09.30 - 11.00	**Session 10: LSST Theme: Informatics and Statistics (Chair J. Bosch)**		
09.30	Inference, Machine Learning and Data Compression for the LSST Era	Hiranya Peiris (University College London, UK)	
10.00	Principled Bayesian Analysis of LSST weak lensing - is it achievable?	Alan Heavens (Imperial College, London, UK)	
10.30	All-sky reference data services of the CDS - preparing for Big Data and the era of LSST	Mark Allen (Université de Strasbourg, CNRS, UMR 7550, FR)	
11.00	Alertsim - Serbian contribution to the LSST	Darko Jevremović (Astronomical Observatory Belgrade, RS)	
11.15	*Tea/Coffee*		
11.45 - 13.15	**Session 11: LSST Science: Solar System (Chair H. Peiris)**		
11.45	Interrelating physical and dynamical characteristics of asteroid populations	Michael Granvik (University of Helsinki, FI)	
12.15	Sizes, binaries, and sheer numbers. The LSST's revolution of outer Solar System, small body science.	Wesley Fraser (Queen's University Belfast, UK)	
12.45	A Linear Feature Detection Algorithm for Detecting Meteors in Astronomical Images	Dino Bektešević (Physics Department, University of Split, Split, HR)	
13.00	Large Synoptic Survey Telescope: Projected Near-Earth Object Discovery Performance	Peter Vereš (Jet Propulsion Laboratory, California Institute of Technology, USA)	
13.15	*Lunch*		
14.30 - 17.30	**Walking tour of Belgrade/FREE**		

20:00 Public talk (Dom Omladine, Makedonska 22)

Thu 23 June 2016

When	What	Who	Comments
09.00-10.30	**Session 12A: LSST Science Workshop A: Stars & Planets**		
	Led by:	Antonella Vallenari (INAF-Padua, IT)	
09.00 - 10.30	**Session 12B: LSST Science Workshop B: Cosmology & Galaxies**		
	Led by:	Sugata Kaviraj (University of Hertfordshire, UK) & Bob Nichol (ICG, University of Portsmouth, UK)	
10.30	*Tea/Coffee*		
11.00 - 12.30	**Session 13A: LSST Science Workshop A: Stars & Planets: continued**		
	Led by:	Antonella Vallenari (INAF-Padua, IT)	
11.00 - 12.30	**Session 13B: LSST Science Workshop B: Cosmology & Galaxies: continued**		
	Led by:	Sugata Kaviraj (University of Hertfordshire, UK) & Bob Nichol (ICG, University of Portsmouth, UK)	
12.30	*Lunch*		
14.00 - 15.30	**Session 14: Tutorial: LSST Simulations**		
	Led by:	Andy Connolly (University of Washington, USA) & Scott Daniel (University of Washington, USA)	
15.30	*Tea/Coffee*		
16.00 - 17.15	**Session 15: Systems and Opportunities (Chair B. Czerny)**		
16.00	LSST Systems Engineering	George Angeli (LSST, Tucson, USA)	
16.30	H2020 Proposal Strategy	Darko Jevremović (Astronomical Observatory Belgrade, RS) & Nicholas Walton (University of Cambridge, UK)	
17.00	BigSkyEarth: Opportunities for LSST in Europe	Dejan Vinković (Science and Society Synergy Institute , HR)	

20:00 Conference Dinner

Fri 24 June 2016

When	What	Who	Comments
09.00 - 10.30	**Session 16: LSST Science: Supernova/Transients/variable stars (Chair P. Astier)**		
09.00	Mapping the dynamics of the local Universe with SNe Ia	Marek Kowalski (Humboldt-Universität zu Berlin Institut für Physik, DE)	
09.30	Supernova Cosmology	Bob Nichol (ICG, University of Portsmouth, UK)	
09.45	The Variability Processing and Analysis of the times series of Gaia	Laurent Eyer (Observatoire de Genève, Université de Genève, CH)	
10.15	PS1 3pi as a pilot survey for panoptic time- domain science	Nina Hernitschek (Max-Planck-Institut fuer Astronomy, Heidelberg, DE)	
10.45	*Tea/Coffee*		
11.15 - 12.30	**Session 17: Feedback from the Workshops and Closing (Chair D. Jevremović)**		
	Led by:	Željko Ivezić (University of Washington, USA)	
12.30	*CLOSE*		

Invited Review

LSST PROJECT STATUS AND UPDATES ON OBSERVING STRATEGY

Željko Ivezić

University of Washington, USA
E-mail: ZIvezic@lsst.org

I will provide status report for LSST construction activities, and discuss ongoing work on observing strategy optimization.

Invited Review

ENABLING LSST SCIENCE: THE LSST DATA PRODUCTS AND SERVICE

Mario Jurić

University of Washington, USA

E-mail: mjuric@astro.washington.edu

The LSST is an integrated survey system. The observatory, telescope, camera and the data management systems will be built to conduct the LSST survey and will not support the 'PI mode' in the classical sense. Instead, the ultimate, science-enabling, deliverable of LSST will be the fully reduced data products and accompanying services.

In this talk, we will present the baseline design and contents of LSST data products. There will be three main categories. "Level 1" data products will be generated continuously every observing night and include measurements such as alerts to objects that have changed brightness or position. These alerts will be made available worldwide within 60 seconds. "Level 2" data products will be made available as annual Data Releases and will include images and measurements of quantities such as positions, fluxes, and shapes, as well as variability information such as orbital parameters for moving objects and an appropriate compact description of light curves. Finally, approximately 10% of LSST's computing capability will set aside for community use in the form of Level 3 services. These enable custom analyses not fully enabled by Level 1/2, while taking advantage of co-location of computation with the entire LSST data set.

Invited Review

LSST SCIENCE COLLABORATIONS

Lucianne Walkovicz

The Adler Planetarium, USA
E-mail: l.m.walkowicz@gmail.com

The LSST Science Collaborations are working groups comprised of members of the scientific community. The nine extant science collaborations represent broad topics of particular interest within LSST science areas. In practice, each collaboration works to provide scientifically-motivated feedback to survey implementation decisions. Collaborations also maintain a robust suite of ongoing research projects within themselves, to prepare for LSST by laying the scientific groundwork in the years up until first light, and to be ready for science in the era of LSST itself. In this talk, I will discuss the structure and activities of the science collaborations, and outline opportunities for joining.

Invited Review

DARK ENERGY SCIENCE COLLABORATION

Andrew Connolly

University of Washington, USA
E-mail: ajc@astro.washington.edu

The Dark Energy Science Collaboration (DESC) is a DOE supported science collaboration whose goal is the study of dark energy with data from the Large Synoptic Survey Telescope (LSST). In this talk I will provide an overview of DESC, the structure of the analysis working groups that cover the five key probes of dark energy: weak lensing, large scale structure, galaxy clusters, supernovae, and strong lensing; the computing working groups that address the computational and simulation needs for DESC; and the technical working groups that provide the connection between dark energy science and the LSST system. I will describe the current objectives for DESC leading up to operations for the LSST and how new international contributors can join and contribute to the objectives of DESC.

Invited Review

THE ROLE OF LSST CORPORATION

Patricia Eliason

LSST Corporation, USA
E-mail: PEliason@lsst.org

I will summarize the role of LSST Corporation as an organization to advance research and education by collaborating in the construction and operation of the Large Synoptic Survey Telescope system.

Invited Review

COSMOLOGY SUPERNOVA SURVEYS WITH LSST

Pierre Astier

LPNHE/IN2P3/CNRS, FR
E-mail: pierre.astier@in2p3.fr

I will discuss the promises LSST can plausibly deliver regarding distance measurements using Type Ia supernovae, from very low redshifts to z$\sim$1. I'll discuss as well a possible extension to higher redshifts relying on Euclid wide-field IR imaging capabilities.

Contributed Talk

THE CONTRIBUTION OF LSST TO EXPLORE THE ULTRA-FAINT SURFACE BRIGHTNESS UNIVERSE

María Cebrián Renau

Instituto de Astrofísica de Canarias, ES

E-mail: mcebrian@iac.es

We will show how future LSST data will be used to explore extremely faint (mu>30 mag/arcsec^2) surface brightness objects: stellar halos of galaxies, intra-cluster light, Galactic cirrus, etc. In this conference, we will describe the advances that our team has done using the 10.4 m GTC telescope to open a new frontier in the studies of integrated light. In particular, we will explain our current photometric deep surveys (8h on sources using broad band filters). We will show, for the first time outside the Local Group, the surface brightness profile down to 33 mag/arcsec^2 of two galaxies: UGC00180, an analogous to M31 located at 150 Mpc and NGC0493, an analogous to MW located at 25 Mpc. We will address in this talk all the systematic problems that appear and their solutions when working at the low surface brightness frontier. Our work is key to maximize the scientific outcome of future imaging facilities such as LSST.

Contributed Talk

DARK ENERGY AND GALAXY CLUSTERING - HOW LSST WILL GAIN FROM THE EXPERIENCE OF VIPERS AND OTHER ESO DEEP SPECTROSCOPIC SURVEYS

Agnieszka Pollo

Jagiellonian University AND National Centre for Nuclear Research, PL
E-mail: agnieszka.pollo@gmail.com

I plan to show the recent results of the present day European deep spectroscopic surveys - in particular, I concentrate on the VIPERS survey, which is - with its 90,000 spectroscopically measured galaxies at $z \sim 1$ in an unprecedentedly large volume ($5 \times 10^7 h^{(-3)}$ Mpc^3) and with an effective spectroscopic sampling $> 40\%$. Evolution of the galaxy clustering - the closest to the present state-of-the-art "local" ($z < 0.2$) surveys. Evolution of galaxy clustering and its relations to galaxy evolution, together with putting constraints on the dark energy equation of state (mainly through redshift space distortion measurements) is among the key goals of VIPERS. Galaxy clustering and properties of dark energy are also one of the main science themes of the LSST. I will show how the results and data from the VIPERS and other ESO spectroscopic surveys can be used to plan, calibrate and interpret future measurements from the LSST, and discuss how to best exploit this synergy.

Contributed Talk

THE CRITICAL NEED FOR PSF TREATMENT IN ULTRA-DEEP IMAGING OF EXTENDED SOURCES

Cristina Martinez-Lombilla

Instituto de Astrofísica de Canarias, ES
E-mail: cml@iac.es

The light of a source is affected by optical parts of telescopes, instruments, detectors, as well as the atmosphere. This results, among other effects, in an increase of the scattered light. The point spread function (PSF) characterises how the light of a source is affected and measures the extent of that scattered light. Thus, the shape of the PSF may vary widely depending on the atmospheric conditions and the instrument used, and is generally time-variable.

In a realistic case, the projected surface brightness structure of a source is convolved with the PSF to make up the observed form. However, previous studies (in particular those by Sandin 2014, 2015) have shown that there is a time and field dependence in the PSF shape. Therefore, if not corrected for, the scattered light adds a systematic component to the observed intensities of our objects. This effect extents to large angular radii, so although the PSF rapidly becomes faint with increasing radius, the integrated amount of light in its faint extended wings can still be significant.

In this work we present an analysis of the PSF effect in ultra-deep data from The IAC Stripe82 Legacy Project. We use multi-band imaging to study the colours and structures in a carefully selected sample of edge-on galaxies with a surface brightness limit of 28.5-29 mag/arcsec^2. We study the radial and vertical surface brightness profiles to study the thick disk component in our sample galaxies, comparing our data with PSF-convolved and deconvolved models. We find that PSF effects, due not only to point sources but especially to extended sources, are critically important, but can be accounted for by careful modelling. We then relate our findings to deep imaging of extended sources with LSST, an area of great promise because of the depth that can be achieved with LSST. We caution to which extent the systematics, including a time-variable PSF shape, will influence results and outline techniques needed to account for them.Careful modelling of the PSF will be critical for any scientific use of LSST imaging of extended sources.

Contributed Talk

LOW SURFACE-BRIGHTNESS SCIENCE USING LSST: UNVEILING THE FUNDAMENTAL MINOR-MERGER PROCESS

Sugata Kaviraj

University of Hertfordshire, UK
E-mail: s.kaviraj@herts.ac.uk

While mergers are fundamental to our structure formation paradigm, our understanding of galaxy merging is largely based on major mergers (mass ratios $>$ 1:4), because such events are more dramatic and easily observable. Nevertheless, a growing literature is indicating that it is, in fact, minor mergers (mass ratios $<$ 1:4), which have a significantly bigger impact on many aspects of galaxy evolution, from stellar-mass and black-hole growth to size evolution. However, studying minor mergers is difficult, because they produce faint tidal features that are almost invisible in current surveys (e.g. standard-depth SDSS imaging). This will change in the LSST era, when deep imaging will become available over tens of thousands of square degrees, making it possible, for the first time, to comprehensively study this fundamental process.

Here we motivate the usefulness of LSST in low surface-brightness (minor-merger) science by presenting a study based on the deep SDSS Stripe 82. We use the Stripe 82 to quantify the likely role of minor mergers in driving stellar-mass growth in the local Universe. Since major mergers destroy discs and create spheroids, morphologically disturbed spirals are remnants of minor mergers. Disturbed spirals exhibit enhanced specific star formation rates (SSFRs), the enhancement increasing in galaxies of 'later' morphological type (which have more gas and smaller bulges). By combining the SSFR enhancements with the fraction of time spirals spend in this 'enhanced' mode, we estimate that $\sim$40 per cent of the star formation in local spirals is directly triggered by minor mergers. Combining our results with the star formation in early-type galaxies - which is minor-merger-driven and accounts for $\sim$14 per cent of the star formation budget - suggests that at least half of the star formation activity in the local Universe is triggered by the minor-merger process. Without a deeper comprehension of this key process, impossible without surveys like LSST, our understanding of galaxy evolution will remain incomplete.

Invited Review

ACTIVE GALACTIC NUCLEI IN THE LSST ERA

Carole Mundell

University of Bath, UK
E-mail: C.G.Mundell@bath.ac.uk

I will review the current observational science case and underlying theoretical framework for AGN with LSST, including a wider perspective of AGN within the context of galaxy evolution. I will highlight the possibilities for new AGN science in the time domain that LSST will open and examine synergies with upcoming international facilities and satellite missions.

Contributed Talk

PHOTOMETRIC REVERBERATION STUDY OF QUASARS IN LSST: STARLIGHT CONTAMINATION

Bozena Czerny[1], Agnieszka Kurcz[2], Magdalena Krupa[2], Agnieszka Pollo[3], Krzysztof Hryniewicz[4] and Justyna Sredzinska[4]

[1] *Center for Theoretical Physics, PL*
[2] *Astronomical Observatory of the Jagiellonian University, Cracow, PL*
[3] *Jagiellonian University and National Centre for Nuclear Research, PL*
[4] *Copernicus Astronomical Center, Warsaw, PL*

E-mail: bcz@cft.edu.pl, agnieszka.pollo@gmail.com

The excellent cadence of the LSST observations will allow to obtain quasar lightcurves in 6 colors, covering timescales up to 10 years. This opens a way to perform the program of measurement of the size of the Broad Line Region in high redshift objects. However, to do that we need to identify all the lightcurve components in the photometric chanenls: strong emission lines, BalmerContinuum, Fe II pseudo-continuum and starlight contamination. We present our new results based on the starlight model developed for the Narrow Line Seyfert galaxy RE J1034+396, which consists of stars of different ages, including young stars, contributing both to the optical and to the UV band, in the rest frame.

Contributed Talk

IMPRINTS OF THE AGN STRUCTURE ON TIME DELAY LIGHT CURVES IN LSST ERA

Dominique Sluse

University of Liege, BE

E-mail: slusedominique@googlemail.com

LSST will provide high quality lightcurves of individual lensed images for several thousands of strongly lensed active galactic nuclei (AGN). The time-delay that will be measured between the lensed images is a key for cosmological inference with time-delay quasars. Those lightcurves also offer a unique probe of the structure of AGN. Indeed, gravitational microlensing caused by stars in the lensing galaxy magnify AGN on scales of micro-arcseconds, providing us with a powerful machine to achieve a one dimensional tomography of the heart of those object. I will explain how the analysis of the chromatic variations of the microlensing signal will allow us to measure the temperature profile of the disc for a large variety of AGN, opening a new road in our physical understanding of AGN. In addition, I will show lightcurves of lensed AGN obtained by the COSMOGRAIL project. Those (single-band) lightcurves have characteristics similar to future LSST data but currently exist for a few tens of objects. Those data suggest that new information on the accretion disc may be retrieved owing to small amplitude rapid microlensing variations now detected in the lightcurves. Those fluctuations of the core microlensing signal indicate that the fine structure of the accretion disc, and possibly relativistic effects, are detected with microlensing. This opens new and exciting outlooks for AGN science foreseen in LSST era.

Contributed Talk

DETECTING SUB-PARSEC SUPER-MASSIVE BINARY BLACK HOLES - LSST PERSPECTIVE

Luka Č. Popović

Astronomical Observatory Belgrade, RS
E-mail: lpopovic@aob.rs

Existence of sub-pc super-massive binary black holes (SMBBHs) in central parts of galaxies is expected, since the merger scenario plays an important role in growing of the mass of central black holes in the center of galaxies. The detection of SMBBHs is especially important for point out the possible source of gravitational waves, and became very actual after recent detection of the gravitational-wave signal GW150914. Here we present some effects that can be detected in the optical spectral range due to a sub-pc SMBBH system presence in the center of an Active Galactic Nuclei. We modeled the variation in characteristics of the spectral energy distribution (SED) and broad optical emission lines of a binary system where both of super-massive black holes have the accretion disk the source of the continuum emission. We explore variability in the SED and discuss the LSST perspective for detection of the sub-pc SMBBH system presence.

Contributed Talk

SYNERGIES BETWEEN LSST AND eROSITA

Joe Mohr

LMU-Munich, DE
E-mail: jmohr@usm.lmu.de

eROSITA is an all-sky X-ray survey mission scheduled for launch in 2017. Over a four year period the mission will survey the sky eight times with XMM-like detectors and a characteristic point spread function of 30" to a depth that will be $\sim$30 times deeper than the ROSAT All Sky Survey at 1 keV. Key extragalactic goals include studies of cosmology and structure formation using a sample of 10^5 X-ray selected clusters and groups and a sample of 10^6 X-ray selected AGN. The LSST dataset will be ideally suited for the completion of the redshift measurements of the clusters and AGN, the weak lensing mass measurements of the parent halos, the study of the associated galaxy populations and the identification of strong lensing events. We present forecasts of the cosmological constraints from the eROSITA+LSST galaxy cluster sample.

Invited Review

LSST AND THE MAGELLANIC CLOUDS

Maria-Rosa Cioni

Leibniz-Institute for Astrophysics Potsdam (AIP), DE
E-mail: mcioni@aip.de

The Magellanic Clouds, with respect to the Milky Way, illustrate a typical example of an early phase of minor merger event. Large fractions of telescope time have been invested to reach the faintest stars, to study their distribution, to measure their age, distance, motion, and chemistry. This effort has resulted in survey projects that span the whole range of the spectrum and in observations from the ground and from space. The LSST is the next step forward in our understanding of the Magellanic Clouds as individual galaxies and of their important role in supplementing material to the Milky Way halo. I will review the status of the Magellanic Clouds and identify the areas where the contribution by LSST will be most effective.

Invited Review

LSST AND E-ELT: COMPLEMENTARY PATHS AND INTERSECTIONS

Gieseppe Bono

Dipartimento di Fisica Universita' di Roma tor Vergata, IT
E-mail: bono@roma2.infn.it

We briefly outline the current status of the E-ELT project. In particular, we will focus our attention on first light and first generation of E-ELT instruments. We present a selection of stellar astrophysics science cases for E-ELT and disucss the role that E-ELT will have on a few open problems concerning resolved stellar populations in nearby stellar systems (globulars, dwarf galaxies). We will also mention the impact that deep, multi-band optical photometry collected by LSST will play in the ELTs era. Finally, we outline the role that high spectral resolution and multi-object spectropgraph will have in addressing current astrophysical and cosmological challenges.

Contributed Talk

THE FRAGMENTATION LIMIT IN THE NEAREST STELLAR CLUSTERS

Nicolas Lodieu

IAC, Tenerife, ES
E-mail: nlodieu@iac.es

The UKIRT Infrared Deep Sky Survey (UKIDSS) Galactic Clusters Survey (GCS) made public near-infrared photometry in six passbands (ZYJHK1K2) and accurate proper motions measured from multiple epochs. The main scientific goal of the UKIDSS GCS was to investigate the shape and universality of the Initial Mass Function (Salpeter 1955) in the low-mass and substellar regimes. Our group extensively exploited the photometric and astrometric data of the GCS in an homogeneous manner to select hundreds of cluster member candidates in several regions with ages in the 3–650 Myr range. We derived luminosity and mass functions in several regions at different ages and found that all mass functions are very similar in the 0.6-0.03 Msun mass interval and in agreement with the log-normal form of the field mass function by Chabrier (2005), pointing towards a universal mass function.

In the meantime, we conducted a deep and widei-field survey of 13.5 square degrees in the Upper Scorpius association with the VISTA telescope. We extracted dozens of planetary-mass candidates confirmed spectroscopically as L dwarf members with VLT/X-shooter, yielding the first-ever sequence in the L dwarf regime (Teff $<$ 2000K). Due to their respective depths at optical and near-infrared wavelengths, LSST and Euclid will bring a step forward in our understanding of star formation in the substellar and planetary-mass regimes. The depth and coverage of the LSST and Euclid surveys will allow us to identify photometric and astrometric members in e.g. Upper Scorpius (5-10 Myr; 145 pc) with masses as low as 2 Jupiter masses according to current state-of-the-art models.

The first part of my talk will present the main results of our homogeneous study of nearby open clusters surveyed by the GCS and our latest result on our substellar sequence below the deuterium-burning limit obtained in Upper Scorpius. The second part of my talk will be dedicated to the unprecedent expectations from LSST and Euclid in the study of the low-mass end of the Initial Mass Function in open clusters and its impact on the theory of the fragmentation limit.

Contributed Talk

THE K2 RR LYRAE SURVEY

Robert Szabo

Konkoly Observatory, MTA CSFK, HU
E-mail: rszabo@konkoly.hu

We have initiated a large survey with K2, the successor of the Kepler space mission to observe thousands of RR Lyrae stars along the ecliptic. The high photometric precision and the 80-90-day continuous coverage will allow us to investigate the light variation of these galactic structure tracer variable stars with an unprecedented detail. The survey will help us to conduct a thorough statistical study of RR Lyrae pulsation dynamics including old and recently discovered dynamical phenomena, like resonances, non-radial modes, period-doubling and the Blazhko-effect. In this talk I describe the survey, present the first results and discuss the prospects in the light of what the combination of the survey and LSST (and also Gaia) will have to offer in the context of galactic structure studies.

Contributed Talk

4MOST - 4-METRE MULTI-OBJECT SPECTROSCOPIC TELESCOPE

Richard McMahon and the 4MOST Consortium

Institute of Astronomy, University of Cambridge, UK
E-mail: rgm@ast.cam.ac.uk

4MOST is a new wide-field, high-multiplex spectroscopic survey facility under development for the 4m VISTA telescope located near ESO, Paranal in Chile. 4MOST has a broad range of science goals ranging from Galactic archeology and stellar astrophysics to the high-energy sky, galaxy evolution, and cosmology. Starting in 2021, 4MOST will deploy 2436 fibres in a 4.1 square degree field-of-view using a positioner based on the tilting spine principle. The fibres will feed one high-resolution ($R \sim 20,000$) and two medium-resolution ($R \sim 5000$) spectrographs, each with fixed 3-channel designs with identical 6k $\times$ 6k CCD detectors. We expect to run 5-year surveys with 4MOST, obtaining more than 5 million spectra per year for the 4MOST consortium and the ESO community. We present an overview of the 4MOST project, its operations concept and ways for the LSST community to get involved, and its anticipated synergies with LSST.

Invited Review

THE LSST SOFTWARE STACK

Jim Bosch and Robert Lupton

Princeton University, USA
E-mail: jbosch@astro.princeton.edu, rhl@astro.princeton.edu

This tutorial will walk participants through writing a simple script to process detrended image files to generate catalogs using the DM stack, and then demonstrate some techniques for using the stack to analyze catalogs and images. If time permits, we may briefly walk through the steps involved in running the current production pipeline prototype on data from an observatory the stack has already be specialized to work with. Participants who want to follow along *must* install the stack and download a small amount of example data in advance.

Installation instructions can be found here (conda binaries are the easiest approach for most platforms): https://pipelines.lsst.io/install/index.html [pipelines.lsst.io]

Example data downloads can be found here:

Invited Review

THE FRENCH DATA ACCESS CENTER

Dominique Boutigny

LAPP - CNRS/IN2P3, FR
E-mail: boutigny@in2p3.fr

The CNRS/IN2P3 Computing Center (CC-IN2P3) located in Lyon is the main data center for high energy physics, nuclear physics and astroparticle physics in France. The National Center for Supercomputing Applications (NCSA) is the lead LSST production data processing center (i.e. the Archive Center for LSST and the Data Access Center for the US).

Following an agreement signed in 2015 with the LSST collaboration, the IN2P3 Computing Center will become a Satellite Data Release Production (S-DRP) center for LSST and will process 50% of the data set needed for the annual releases. During this process, CC-IN2P3 will host a complete copy of the LSST data (raw data and data products).

In order to provide the computing resources necessary for the scientific exploitation of the LSST reduced data, the CC-IN2P3 will design, deploy and operate a Data Access Center (DAC). Services provided by the French DAC will be used by individual researchers or group of researchers who need to process the LSST reduced data for their specific research program. Primarily designed for the IN2P3 LSST scientists, the French DAC could be extended to a wider community, provided that adequate funding and agreement are settled.

Currently under active design, the French DAC will include the following main components:

- A data repository for storing and serving both the data resulting from the LSST S-DRP and the data produced by the individual scientists using the other DAC components presented below;
- A distributed database system based on the LSST Qserv product to store the catalog of astronomical objects;
- A High Throughput Computing (HTC) farm to run embarrassingly parallel applications;
- A parallel / large memory facility optimized for the execution of large-scale multiprocessor applications such as cosmology parameter fits;
- A User Interface and visualization system;
- A data distribution system which will allow authorized individual scientists to download datasets to their local facilities (e.g. their personal computer or group cluster).

I will present the status of the design of the French DAC with its various options as well as the research and development activities which are pursued in coordination with the LSST Data Management (data exchange technologies, Qserv test bench, etc.).

Invited Review

INFERENCE, MACHINE LEARNING AND DATA COMPRESSION FOR THE LSST ERA

Hiranya Peiris

University College London, UK
E-mail: h.peiris@ucl.ac.uk

I will highlight several efforts with strong European involvement in these areas, under development for use in LSST and precursor imaging surveys: hierarchical Bayesian modelling for inference of galaxy redshift distributions; machine learning classification for photometric supernovae light curves; and 3D data compression for galaxy clustering and cosmic shear.

Invited Review

PRINCIPLED BAYESIAN ANALYSIS OF LSST WEAK LENSING - IS IT ACHIEVABLE?

Alan Heavens

Imperial College London, UK
E-mail: a.heavens@imperial.ac.uk

From a Bayesian perspective, the posterior probability distribution of the cosmological model parameters encapsulates our state of knowledge after data are collected. This is arguably the main goal of the statistical analysis of data. However, it is by no means trivial to compute the posterior, but recent advances in theoretical methods and computational techniques mean that it is now within reach to draw many samples from this multidimensional object. In the case of LSST weak lensing the dimensionality of the parameter space is enormous - millions of dimensions, since a Bayesian analysis will also draw samples of not just the power spectra, but also the shear distortion, providing also mass mapping as a byproduct. By using fast spherical harmonic transforms, messenger fields, and some tricks to improve convergence, Bayesian Hierarchical Models can be used to solve this challenging problem. I will show how this works both on simulated data, and also on data from the leading completed ground-based weak lensing survey, CFHTLenS, and consider how this will scale to LSST proportions.

Invited Review

ALL-SKY REFERENCE DATA SERVICES OF THE CDS - PREPARING FOR BIG DATA AND THE ERA OF LSST

Mark Allen

Observatoire astronomique de Strasbourg, Université de Strasbourg, CNRS, UMR 7550, FR

E-mail: mark.allen@astro.unistra.fr

The Strasbourg astronomy data centre (Centre de données astronomiques de Strasbourg, CDS) develops services for the global use of astronomical reference data: SIMBAD is a database of astronomical object identifications and bibliography; the Vizier service publishes catalogues and data associated with journal articles and also major surveys, including billion row catalogues, and has an associated fast positional cross-matching service; the Aladin sky atlas is a visualisation and integration tool that provides access to hundreds of imaging and 3-d data cube surveys and also to resources available in the Virtual Observatory. These services aim to make heterogeneous data accessible and interoperable via the use of standardised metadata, and considerable effort is being made to ensure the scalability of these services in order to handle future Big Data surveys. The recent developments of the Hierarchical Progressive Survey (HiPS) scheme and Multi-order coverage maps (MOC) based on HEALPix are a part of this approach. HiPS and MOC have proved to be practical solutions for managing all-sky data sets (images, cubes and catalogues) and are enabling new levels of interoperability between data sets and between services. The simplicity and scientific features of HiPS, as well as its and ease of implementation in Aladin Lite has led to the creation of a network of data centres publishing HiPS data sets. We will highlight the features of HiPS and MOC and their potential application to data expected from LSST, as well as other topics related to the use and creation of reference astronomy data in the era of LSST.

Contributed Talk

ALERTSIM - SERBIAN CONTRIBUTION TO LSST

Darko Jevremović

Astronomical Observatory Belgrade, RS
E-mail: darko@aob.rs

We will review alert simulator for LSST developed by Belgrade group. This simulator will be used in testing funcionality of external event brokers/CEP engines. It is based on current simulation framework and allows for different classes of objects to be 'alerted'.

Invited Review

INTERRELATING PHYSICAL AND DYNAMICAL CHARACTERISTICS OF ASTEROID POPULATIONS

Mikael Granvik

University of Helsinki, FI
E-mail: mgranvik@iki.fi

The interior structure and interior composition of asteroids is one of the key knowledge gaps in planetary science. A better understanding of asteroid interiors is essential for a wide range of topics such as developing efficient technologies for asteroid impact mitigation, constraining models of the formation and evolution of the Solar System, identifying the origin of Earth's water, and improving the surface chronology of planets and moons. Information of the structure of asteroids has primarily been based on their density estimates combined with rotation characteristics. An alternative approach for constraining models of asteroid interiors, particularly in terms of their composition, was recently identified while developing a state-of-the-art model of the orbit and absolute-magnitude distributions of near-Earth asteroids. We showed that, contrary to a more than 20-year-old theory, near-Earth asteroids are completely destroyed at non-trivial distances from the Sun (Granvik et al. 2016, Nature 530, 303). Our results suggest that kilometer-scale asteroids are destroyed at perihelion distances of about 10 solar radii whereas decameter-scale asteroids disrupt at perihelion distances of about 40 solar radii. Although all asteroids are eventually destroyed we also found that dark asteroids are destroyed at larger perihelion distances. The exact mechanism causing the destruction has not yet been identified but we have ruled out tidal disruption and direct sublimation of silicates. Given the approximate range of surface temperatures and the fact that dark and presumably volatile-rich asteroids are destroyed easier, a potential explanation could be that volatiles inside the asteroids are heated up until they start sublimating and this causes the pressure below the regolith layer to increase until the volatiles are suddenly released in a super-catastrophic disruption event. It therefore appears reasonable to assume that the disruption distance should be correlated with the (interior) composition if all other parameters are held constant. To test potential disruption mechanisms and constrain the interior characteristics of asteroids with this technique we need to i) extend the sample of known near-Earth asteroids to smaller sizes, ii) increase the sample of known asteroids at small perihelion distances, iii) have a good understanding of the selection effects affecting of the survey, and iv) get color information that would allow the classification asteroids based on their surface properties. The Large Synoptic Survey Telescope promises to fill all these needs during its 10-12-year survey.

Invited Review

SIZES, BINARIES, AND SHEER NUMBERS. THE LSST'S REVOLUTION OF OUTER SOLAR SYSTEM, SMALL BODY SCIENCE

Wesley Fraser

Queen's University Belfast, UK
E-mail: wes.fraser@qub.ac.uk

The UK has become a partner in the Large Synoptic Survey Telescope Science Consortium. Expecting to detect and optically characterize over 6 million Solar System Objects, the LSST represents a major fundamental step forward in large scale Solar System survey science. I will discuss the basic observing strategies utilized by the LSST, and how those strategies impact small body observation. In particular, I will discuss the issues of tracking and orbit tracklet contamination, which have been, and will remain as significant issues for large area surveys such as the LSST.

I will also discuss various aspects of small body science in which the LSST will have a massive impact. Including a small dose of what the LSST will not be able to do. LSST's will contribute massively to a range of subjects, including light curve characterization, colour measurement, and occultation detection. In particular, I will emphasize the LSST's order of magnitude improvement over current measures of the small body size distribution, and phase-curve distribution of Kuiper Belt objects, Sedna-like objects, and the Jupiter Trojans. In addition, I will discuss the not so obvious science products, including binary characterization, and occultation prediction. Finally, I will discuss the possibility that the LSST may directly discover the purported planet Nine.

Contributed Talk

A LINEAR FEATURE DETECTION ALGORITHM FOR DETECTING METEORS IN ASTRONOMICAL IMAGES

Dino Bektešević

Science and Society Synergy Institute, HR
E-mail: ljetibo@gmail.com

Long linear features in astronomical images are largely treated as unwanted noise due to satellite and airplane tracks, diffraction spikes, etc. However, some of the lines are created by meteors and can be a valuable source of meteor data. Large surveys are especially suitable for this as they have an extensive time coverage over a significant fraction of the sky. The problem is that current linear feature detection algorithms are very inefficient in detecting the existence of lines in astronomical context. We have been developing a new algorithm that can be used for this purpose and tested it on the SDSS survey images. The algorithm first searches for bright lines and in case of no detection it applies a more complex strategy to detect possible low brightness lines. The benchmarking on a subset of hand-checked SDSS frames with lines reveals that the algorithm detects about 70-80% of frames with linear features. The bright lines are detected mostly within 0.1 seconds, while dim lines take less than 0.3 seconds. In the post-processing phase we reject non-meteor lines to create a catalogue of SDSS meteors and proceed with extracting meteor science data.

Contributed Talk

LARGE SYNOPTIC SURVEY TELESCOPE: PROJECTED NEAR-EARTH OBJECT DISCOVERY PERFORMANCE

Peter Vereš and Steve Chesley

Jet Propulsion Laboratory, USA

E-mail: veres@jpl.nasa.gov, steve.chesley@jpl.nasa.gov

We conducted a study to examine Near-Earth Object (NEO) search performance of various LSST search strategies with a focus on realistic use of observational and technological constraints. To speed-up processing, we have randomly selected 3000 NEO orbits from Grav et al. (2011) synthetic NEO population and set the absolute magnitude (H) to zero. This simplified population allowed visibility of all objects independently of distance and boundary conditions and the ability to control H in post-processing. The above mentioned low fidelity approach was verified with a full density NEO simulation.

Ephemerides of NEOs in LSST pointings as well as the linking of detections into tracklets were performed by the Pan-STARRS Moving Object Processing System (MOPS, Denneau et al., 2013). MOPS was improved to include constraints simulating realistic conditions, including real shape of the LSST field which was rotating between visits, limiting magnitude fading, statistical fill factor, signal-to-noise trailing loss, vignetting, asteroid colors and light curve amplitude variation. We also included scenarios with overestimated limiting magnitudes and artificial upper threshold in NEO's rate of motion. CPU time was optimized by using parallel computing through Condor on an 8-core linux cluster.

Four LSST survey models were tested: the baseline survey enigma_1189, three-visit optimized enigma_1271, four-visit optimized enigma_1266 and suggested new baseline survey minion_1016. Each survey has 5 observing proposals and ran for 10 years, however, we removed the Cosmological Deep Drilling proposal from our simulations. We also restricted the maximum leg between the first and last visit of the same field in a night to 2 hours for making a tracklet. Tracklets were created in a velocity range between 0.05 and 2.0 deg/day. Even though inter-night linking was not turned on, we estimated the upper number of possibly created tracks by requiring existence of three tracklets within a given time. This way we constructed potential 12-day and 20-day tracks.

Results showed that the detection efficiency for NEOs brighter than H<22 observed at least once in the baseline surveys was about 88%, falling down to 62% for 20-day tracks. Surprisingly, the penalty of using three or four-visit optimized surveys was relatively small with respect to the baseline surveys. Generally, the studied observational constraints affected detection efficiency more at the faint end. The strongest effect was seen if the limiting magnitude was overestimated, where at the penalty of systematic -0.5 mag offset, the efficiency for 20-day tracks would fall from 62% to 55%. Fast moving and therefore trailed NEOs were not crucial for building tracks because most of the small NEO were also detected at greater geocentric distance and at lower velocities. Thus, decreasing the upper velocity tracklet threshold to 1 deg/day will only causes the 20-day track efficiency to go down by only 1%. Increasing the threshold to 5 deg/day will only gain 1% in efficiency.

Invited Review

TUTORIAL: LSST SIMULATIONS

Andrew Connolly and Scott Daniel

University of Washington, USA
E-mail: ajc@astro.washington.edu, scottvalscott@gmail.com

The accurate detection and characterization of variable and transient sources is an important science goal for the LSST. In order to evaluate the performance of any proposed observing cadence at meeting that goal, researchers must have access to realistic simulations both of the variable/transient population of the universe and of the behavior of LSST itself. OpSim (the Operations Simulator) is a software tool designed by the LSST project to take fiducial scheduling algorithms and produce high fidelity simulations of the 10 year observing cadences they produce. OpSim includes accurate characterizations of all of the expected mechanical performances and tolerances of the LSST telescope and is designed to interface with scheduling algorithms exactly as the actual telescope will. CatSim (the Catalog Simulator) is a series of data and software products designed to provide users with an accurate simulated fiducial universe to observe with the OpSim simulated survey. It contains distributions of galaxies drawn from N-body simulations, distributions of Milky Way stars based on SDSS data, and SED and variable light curve libraries based on the latest theoretical and phenomenological models. In this tutorial, we will demonstrate how to use OpSim and CatSim to produce accurate LSST light curves for variable and transient populations with photometric uncertainties expected from the LSST system. This should allow researchers to effectively evaluate the performance of LSST at identifying and characterizing variable populations of their choice.

Before attending this tutorial, participants will want to install CatSim and download a fiducial OpSim output.

To install CatSim (please do not do this until 3 days before the conference, we are still optimizing some of the functionality that will be demonstrated):

1) Install Miniconda. Miniconda is a software distribution tool (like pip or yum) used to distribute python and many of the most useful python-based software tools. If you do not already have Miniconda (or the heavier-duty Anaconda), go to: http://conda.pydata.org/miniconda/html and follow the installation instructions found there. Be sure to install the python 2.7 version. The LSST Simulations stack is not yet python 3 compliant.

2) Miniconda provides you with a distribution of python as well as the software tool conda for downloading and installing new packages. In order to use these tools, they must be on your PATH. Prepend the directory $MINICONDA_HOME/bin to your PATH (where MINICONDA_HOME is the directory where Miniconda was installed). If you are running a bash shell, this will look something like:

```
cd my/miniconda/directory/
export PATH=$PWD/miniconda2/bin/:$PATH
```

you should now be able to type

```
which conda
```

and see the path to the conda executable installed by Miniconda

3) Miniconda's conda tool installs software from a series of distribution servers that Miniconda knows about. Now you must tell Miniconda about the server that contains the LSST Simulations software. Run the command

```
conda config –add channels http://eupsforge.net/conda/dev
```

4) Install MAF by running

```
conda install lsst-sims
```

This will take about half an hour.

5) Confirm that the installation was successful. There are a few steps you will need to run through whenever you want to use CatSim.

a) Open a new terminal.
b) Add $MINICONDA_HOME/bin to your PATH as in step(2)
c) Run

```
source eups-setups.sh
```

This sets up a version of EUPS, the package management software that handles version control for LSST Software.

d) Run

```
setup lsst_sims -t conda
```

This will tell EUPS to setup the conda-installed version of CatSim.

e) Now, verify that MAF has successfully been installed by opening a python session and try import lsst.sims.utils

If you do not get any errors: congratulations! You have successfully installed CatSim. We will show you want to do with it in Belgrade.

To download the OpSim data, go to

http://lsst.org/scientists/simulations/opsim/opsim-v335-benchmark-surveys

scroll down to the table at the bottom of the page, and download the SQLite Data for kraken_1042. This will be about 5GB of data.

Invited Review

SYSTEMS ENGINEERING, VERIFICATION, AND COMMISSIONING FOR LSST

George Z. Angeli, Chuck Claver, Bo Xin and Brian Selvy

LSST, USA
E-mail: GAngeli@lsst.org

Systems engineering is the art of managing technical complexity. The Project Systems Engineering (PSE) team manages the complexity of LSST's diverse enterprise through well-established and rigorous processes for requirements, configuration and change management, performance analysis and tracking, interface control, quality assurance and risk management. The LSST PSE has used these processes to manage the breakdown of the complex LSST system into smaller, more convenient subsystems, and will apply them as the reintegration of those pieces proceeds into the delivered system fitting its purpose. With LSST being well in construction, the role of systems engineering is threefold: (i) exercise technical oversight of construction and integration to ensure that overall system performance is not compromised in the process, (ii) establish a comprehensive verification (test) regime and ensure its integrity, and (iii) manage the integration of the individual subsystems into the observatory system and then the commissioning of the observatory. At the heart of the technical oversight are trade studies evaluating change and waiver requests relative to the key performance metrics. As an extension to our well established end-to-end simulation framework, LSST Systems Engineering developed an integrated modeling framework capable of linking technical specifications and engineering tolerances/deviations to key optical system performance. Besides a brief overview of the framework, the presentation will highlight a few critical trade studies and their conclusions. Currently we are in the process of establishing the detailed Observatory Verification Plan, including the supervision of its realization. The Verification Plan includes (i) verification methods for each system level design and interface requirement, (ii) verification requirements and success criteria, and (iii) sequencing and grouping verification activities into verification events. Supervision of its realizations encompasses (a) maintaining the system level Verification and Compliance Matrices from planning to final acceptance, (b) reviewing and assessing verification reports, as well as (c) conducting verification readiness and status reviews.LSST commissioning is scheduled to start in October 2019 and will be carried out in three phases of activity leading to operations readiness. The first phase, Early System Integration & Test, utilizes a commissioning camera (ComCam) with 9 LSST engineering grade sensors and many of the interfaces found in the full science camera. ComCam enables early testing of the telescope, Observatory Control System and Data Management Science pipelines. The second phase, Full System Integration & Test,, integrates the full science camera enabling the complete commissioning of the Camera, Telescope and Data Management subsystems. Lastly, the third phase, Science Verification will conclude commissioning by running the system to perform a mini-survey over roughly 8-10 weeks to demonstrate operations readiness and characterize the system to the survey performance specifications in the Science Requirements Document. The 3-phased commissioning plan, basic schedule and budget were developed as part of the LSST Project's preparations for its Final Design Review held December 2013. Current activities aim to further detail this plan and align it to the Observatory Verification Plan. It also encompasses the coordination of early inter-subsystem handoffs and joint pathfinder activities. As part of this activity, software and hardware tools unique to commissioning need to be specified, designed, purchased and/or constructed, as well as validated. A preliminary design level review of the Commissioning Plan is planned for November 2016. This will be followed by a Commissioning readiness review late in 2018. Through the use of rigorous methods, high fidelity simulations and analysis, and careful detailed verification and commissioning planning the PSE expects to successfully usher LSST into full survey operations as early as September 2021 and no later than October 2022.

Invited Review

H2020 PROPOSAL STRATEGY

Darko Jevremović[1] and Nicholas Walton[2]

[1] *Astronomical Observatory Belgrade, RS*
[2] *Institute of Astronomy, University of Cambridge, UK*
E-mail: darko@aob.rs, naw@ast.cam.ac.uk

We will review current and future opportunities for submitting H2020 proposals with significant LSST involvement. Target of those proposals could be networking in general for exchange of experiences, training networks for educating younger generation of astronomers and/or infrastructure projects including e-infrastructures. We expect that discussion will follow with exchange of ideas.

Contributed Talk

BIGSKYEARTH: OPPORTUNITIES FOR LSST IN EUROPE

Dejan Vinković

Science and Society Synergy Institute, HR
E-mail: dejan@iszd.hr

BigSkyEarth (http://bigskyearth.eu) is a Horizon 2020 funded COST network designed to bring together communities from public and private sector interested in astronomy and Earth observation dependent on 'big data' developments in computer science, statistics, and data analysis. The role of BigSkyEarth is to boost communication within and between the communities, and identify common solutions to challenges faced in research and industry across them. BigSkyEarth organizes meetings of various types, training schools, financially supports exchange of experts between countries and works on joint activities. European LSST network can join the BigSkyEarth activities to help achieve its own science goals and get closer to a wider community of big data experts.

Invited Review

MAPPING THE DYNAMICS OF THE LOCAL UNIVERSE WITH SNe Ia

Marek Kowalski

Humboldt-University Berlin, DE

E-mail: marek.kowalski@desy.de

Supernova Ia serve as excellent distance indicators beyond redshift one, yet, they also have a special role in the nearby Universe. I will discuss recent results on determining the Hubble constant and measure bulk flows using nearby SNe Ia from the Supernova Factory, a spectrophotometric survey of SNe Ia. In the second part of the talk will review the Zwicky Tansient Facility, an all-sky survey which will start taking data in 2017 and provide a new anchoring sample of nearby SNe for the LSST era.

Contributed Talk

SUPERNOVA COSMOLOGY

Bob Nichol

University of Portsmouth, UK
E-mail: bob.nichol@port.ac.uk

Supernova cosmology with LSST will go beyond the usual Hubble Diagram. I will discuss possibilities to test cosmology through the use of new supernova types (e.g. superluminous) and using new techniques like SN lensing. I will present lessons we are learning from DES as well as predictions for what LSST will provide. I will also discuss plans for spectroscopic follow-up of LSST SNe.

Invited Review

THE VARIABILITY PROCESSING AND ANALYSIS OF THE TIMES SERIES OF GAIA

Laurent Eyer

University of Geneva, CH
E-mail: laurent.eyer@unige.ch

A general overview of the variability processing and analysis tasks will be presented from the point of view of the Gaia DPAC consortium. In other words: what are the methods that we used to tackle the global analysis of the Gaia data. Our goal is to systematically detect variable objects, classify them, derive characteristic parameters for specific variability classes, and give global descriptions of variable phenomena.

Invited Review

PS1 3PI AS A PILOT SURVEY FOR PANOPTIC TIME-DOMAIN SCIENCE

Nina Hernitschek

Max-Planck-Institut fuer Astronomy, Heidelberg, DE
E-mail: hernitschek@mpia.de

The Large Synoptic Survey Telescope is a survey system that will image the sky in six optical bands from 320 to 1050 nm, uniformly covering approximately 18,000 deg^2 of the sky over 800 times. It will result in a huge amount of multi-band and non-simultaneous data. Once operational in 2022, the LSST will explore a wide range of astrophysical questions, from discovering killer asteroids to examining the nature of Dark Energy.

For examining possibilities and challenges in doing science with data from such a survey that is multi-band and non-simultaneous, the Pan-STARRS1 (PS1) 3p can be used as a pilot survey. This is especially important to explore the possibilities in detection and classification of variable sources within the first years of LSST when only a fraction of the total observing time of 10 years is done.

We had explored the capabilities of PS1 3pi for carrying out time-domain science in a variety of applications. we had used structure function fitting as well as period fitting, to search for and classify high-latitude as well as low-latitude variable sources, in particular RR Lyrae, Cepheids and QSOs.

Poster

TESTING ASTEROID LINKAGE PERFORMANCE WITH THE BASELINE LSST CADENCE

Steven R. Chesley and Peter Vereš

Jet Propulsion Laboratory, California Institute of Technology, USA
E-mail: steve.chesley@jpl.nasa.gov, veres@jpl.nasa.gov

We report on the results of simulations designed to test the feasibility of linking non-stationary LSST transient detections to derive orbits of moving objects. This effort hinges critically on having high-fidelity, full-density models for both spurious detections and detections of simulated solar system objects. It does not require long term simulations, and for most tests we only run 2-3 observing cycles (i.e., lunations).

For the synthetic moving objects in the simulation we use 14 million main belt asteroids and 860,000 near-Earth objects. The astrometric positions of the detections are computed with milli-arcsecond accuracy and then errors are added to account for realistic measurement noise. We also inject false detections derived from random noise and artifacts arising from image differencing, which are not generally randomly distributed.

We use the Moving Object Processing System (Denneau et al. PASP 125, 2013) to derive lists of detections, including both synthetic asteroids and false detections. For a given LSST observing cycle this includes of order 14 million asteroid detections and even more false detections, depending on the false detection model applied. These false detections are used to form tracklets with a 2 deg/day rate of motion cutoff and these tracklets are used to construct tracks and orbits. Preliminary results, using only random false positives, indicate that orbit completeness in excess of 95% are readily obtained and higher values are expected by better tuning of the linkage process. The purity of the resulting orbit catalog is in excess of 99.9% in cases run to date. However, we have not yet employed realistic models for image differencing artifacts and this may have a significant impact on performance.

Poster

CEPHEIDS AND RR LYRAE STARS AS STANDARD CANDLES AND STELLAR POPULATION TRACERS: THE GAIA-LSST SYNERGY

Gisella Clementini

INAF Osservatorio Astronomico Bologna, IT
E-mail: gisella.clementini@oabo.inaf.it

In its multi-epoch, unbiased monitoring the all sky, Gaia will discover and measure position, trigonometric parallax, proper motion and time-series photometry of thousands Cepheids and RR Lyrae in the Milky Way (MW) and its surroundings, down to a faint magnitude limit of G$\sim$20.7 mag. The complete census of Galactic Cepheids and RR Lyrae along with the unprecedented precision and accuracy of Gaia measurements for local Cepheids and RR Lyrae will allow a breakthrough in our understanding of the MW structure and a global re-assessment of the whole cosmic distance ladder from local to cosmological distances. LSST will extend Gaia's horizon to a limit about five magnitudes fainter. We specifically discuss the synergy existing between Gaia and LSST in the use of Cepheids and RR Lyrae stars as standard candles and stellar population tracers.

Poster

SYSTEM FOR AUTOMATIC DETECTION OF OBJECTS WITH FAST VARIABILITY ON MONITORING MULTIPLE EXPOSURE PLATES

Nikolay Ivanov[1] **and Milcho Tsvetkov**[2]

[1]*Sofia University, Faculty of Mathematics and Informatics, Department of Informatics, Artificial Intelligence, BG*
[2]*Institute of Mathematics and Informatics, BAS, BG*

E-mail: milcho.tsvetkov@gmail.com

We present our work for registration of sporadic outbursts and periodic brightness variations of different types of astronomical objects on digitized direct multi-exposure photographic plates obtained in the frames of long term monitoring with wide-field optical telescopes. Monitoring observations of Omicron Velorum (IC2391) stellar cluster (age of 3×107 years), obtained in the period 1985-1990 at the European Southern Observatory (ESO, La Silla, Chile)) have been used. A new way of extracting data from large arrays astronomical observations (data-mining) with modern methods of artificial intellect approaches is proposed. The astronomical observations are unique and each new handling is of particular scientific interest suggesting new results. Effective algorithms as automated alternative to the used traditionally method for visual comparison (blinking) of astronomical images in relatively large fields of view (from 2 to 30 sq. degrees) are discussed.

Poster

PHASE DISPERSION MINIMISATION AS A TOOL FOR ANALYSIS OF LONG-TERM BRIGHTNESS VARIATIONS

Tomislav Jurkić

Department of Physics, University of Rijeka, HR
E-mail: tjurkic@phy.uniri.hr

Long-period variables such as Mira stars often show long-term variations in brightness superimposed on their periodic changes caused by pulsations. Long-term variations can be periodic or non-periodic, caused by orbital motion, presence of dust or by some other physical mechanism. In order to remove periodic short-term variations and study only the long-term component, we propose Phase dispersion minimisation (PDM) method as an efficient tool and a method of choice. PDM is a very robust and precise method, capable of efficiently removing short-term periodic variations regardless of the shape of the light curve. It greatly reduces the number of free fitting parameters usually used by other techniques as the pulsation period is the only parameter to be determined. If the phase diagram is fitted to the Fourier polynomial, other pulsational parameters can be also determined. We have successfully applied PDM method in analysis of light curves of symbiotic Miras HM Sge and RR Tel, and compared the results with the values obtained by Discrete Fourier Transform (DFT), another widely used method. Our results show that PDM method is efficient in reducing the light curves for short-term periodic variations and can be applied in larger stellar samples expected to be obtained by surveys such as LSST.

Poster

ADAPTATION OF LSST SOFTWARE STACK TO ESO-NTT SOFI NEAR-INFRARED CAMERA

Yana Khusanova[1], Darko Jevremović[2] and Sonia Giovanna Temporin[3]

[1] *University of Innsbruck, AT*
[2] *Astronomical Observatory Belgrade, RS*
[3] *Institute for Astro- and Particle Physics, University of Innsbruck, AT*

E-mail: yana.khusanova@student.uibk.ac.at, darko@aob.rs, giovanna.temporin@uibk.ac.at

The LSST Software Stack is adaptable for processing of data obtained with different cameras. The purpose of this work is to create an obs_sofi package enabling support of the ESO-NTT SOFI Near-Infrared Camera. Our first step was to create basic parts of the obs_ <camera> package for implementation in the Software Stack: an ingester to build the registry of data, a camera mapper which navigates through a repository with the data and a camera geometry description. The second step was to adjust the standard procedures of data processing to the near-infrared data obtained with SOFI. There are several differences in working with near-infrared data compared to the optical:

due to the high and variable sky background it is impossible to take one long exposure and therefore one needs to obtain several dithered exposures with short integration time and coadd them;

since dark currents are high for NIR detectors and the bias-pattern is also a function of the incident flux, it is necessary to use dark exposures rather than zero exposures and consider bias an inherent part of the dark exposure.

These differences define the specifics of working with the data from the SOFI-camera and from NIR detectors in general. Our procedure for instrument signature removal includes dark subtraction, flat field correction, and a finer correction step to remove a remaining residual pattern along the y-axis. We are now optimizing the process for obtaining the final coadded image. For this purpose we create a non-uniform weight-map for each exposure to take into account inhomogeneous noise levels across the individual images and we explore methods for obtaining a sufficiently accurate alignment of the dithered exposures. Here we present the results of our adaptation of the LSST Software Stack as applied to an example of Ks-band data set obtained with SOFI-Camera. We discuss the differences between the results obtained with the LSST Stack and those of the analogous reduction performed with IRAF and other publicly available software.

Poster

WALSH ANALYSIS - A CONVENIENT PREPROCESSOR FOR PERIOD DETECTION IN ASTRONOMY

Miodrag Malović[1] and Darko Jevremović[2]

[1] *Innovation Center, Faculty of Technology and Metallurgy, University of Belgrade, RS*
[2] *Astronomical Observatory Belgrade, RS*

E-mail: office@malovic.in.rs, darko@aob.rs

Walsh analysis is practically analogous to Fourier analysis, except that square wave is used instead of the sine one. It has one major advantage over Fourier - it can be performed much faster. This may seem of little importance at first, since computers have gotten to the point where most programmers do not take any care about the size of their code or the speed of their calculations. However, LSST will provide astronomers with huge data sets, and searching for periodicity peaks with high resolution might require enourmous amount of calculations. To perform this analysis in real time (a matter of seconds) it is important to skip non-necessary mathematical operations and focus on applying complex period detection algorithms (such as line fitting, analysis of variance, and others) only in the vicinity of expected peaks, not on all arbitrary periods. To do this efficiently, we propose that Walsh analysis is applied on the data first. A simulation was conducted with artificially generated light curves for the three types of variable stars: RRLyr, Algols and classical cepheids. LSST current baseline cadence (enigma_1189) was used for the timing of samples.

Poster

SUNDIAL - A NEW EU-FUNDED TRAINING NETWORK COMBINING ASTRONOMY AND COMPUTER SCIENCE

R. F. Peletier[1], J. H. Knapen[1], G. Longo[2] et al.

[1]*Instituto de Astrofísica de Canarias, ES*
[2]*Department of Physical Sciences, University of Napoli Federico II, IT*
E-mail: jhk@iac.es

SUNDIAL (SUrvey Network for Deep Imaging Analysis and Learning) is a new EU-funded Innovative Training Network (ITN) that has been funded by the EU and will formally run from 1 April 2017 for four years. It will combine astronomy with computer science and train a group of 14 young scientists, focussing on techniques of automated learning from large quantities of data to answer fundamental questions on the evolution of properties of galaxies. While these techniques will lead to major advances in our understanding of the formation and evolution of galaxies, we will also promote, in collaboration with industry, much more general applications in society, e.g. in medical imaging or remote sensing. We have put together a team of astronomers and computer scientists, from academic and private sector partners, to develop techniques to detect and classify ultra-faint galaxies and galaxy remnants in a deep survey of the Fornax cluster, and use the results to study how galaxies evolve in the dense environment of galaxy clusters. With a team of young researchers we will develop novel computer science algorithms addressing fundamental topics in galaxy formation, such as the huge dark matter fractions inferred by theory, and the lack of detected angular momentum in galaxies.

The Network, led by the University of Groningen, will soon recruit 14 PhD students with prior formation in astronomy and computer science. We will offer competitive salaries and employment conditions, and the chance to be trained within a unique network of world-class astronomers and computer scientists. The aim of this poster is to make colleagues aware of our new Network, and of the opportunities for employment for students they may know within their own universities, institutes, or countries.

Poster

SIMULATION OF THE DISTORTION OF THE TELESCOPIC OPTICAL SYSTEM

Stevo Šegan, Dušan Marčeta and Kristina Racković Babić

Department of Astronomy, Faculty of Mathematics, University of Belgrade, RS
E-mail: rackovick@yahoo.com

In absence of real observation and telescope optic we have numerically and statistically simulated parameters such optical system and observations. We have used Turner's extended equations to describe influence of all optical system aberrations with special attention dedicated to the distortion of field of image and to the modeling of aperture (field of view) stop parameter. Statistical behavior of the vector distortion is recommended as indicator of stability of the optical system. Reliable virtual observation reduction and determination of the coordinates of the such objects is given for significantly increased number of reference objects. The number of reference objects was greater than 20 and apparent places of stars are calculated via Equinox Method of stellar reduction, using some procedures from SOFA astrometry package and using JPL DE405/LE405 barycentric ephemeris, referred to the ICRS, from Web-interface of Jet Propulsion Laboratory. The type of reduction equation used to determine the coordinates of a new celestial body depends on the quality of the telescope field and on the specific problem considered. Thus, if a given object and the reference stars are found within a small (central) section of the image, we can use only the first three (linear) terms of the Turner's equations with adding forth one, for distortion. The theory of shooting the sky through telescopes and eliminating aberration is reduced to the application of the Turner's formula (Turner, 1893) of first or second order. We have assumed that, for all astrometric tasks, our telescope (as photographic camera), its aperture and field stops is quality enough to be attributed to the Turner's first order equations. This linear model of error description means that all elements are perpendicular to the optical axis, stops and surfaces are centered (axially) and there is perfectly collimated system. Collimation is the procedure of aligning the objective optics with the eyepiece optics, focal reducer or cameratelescope focal plane so that they share a single optical axis. If it is not as above described, the second order Turner's formula must be used. The modified Turner's formula does not guarantee any improvement in the description of distortion, especially if the optical system of the telescope collimation procedure failed. All in all, we applied the modified formula to calculate coordinates of reference stars a radio source for which the scattering of the measured data was the greatest.

Poster

GRAWITA: OBSERVING THE ELECTROMAGNETIC COUNTERPARTS OF GRAVITATIONAL WAVE SOURCES

Giulia Stratta

Urbino University, IT
E-mail: giulia.stratta@uniurb.it

The era of gravitational astronomy has officially started on September 14, 2015 with the first detection of gravitational waves (GW150914) achieved by the Advanced Laser Interferometer GW Observatory (aLIGO) and Advanced Virgo (aVirgo) collaboration. Realistic detection rate by 2022 is of hundreds of GW sources per year in the high frequency range accessible to ground-based interferometers (1-10000 Hz), with sky localizations of the order of a few 10 square degrees or less.

A wealth of additional and/or complementary information on the GW source nature is provided by its electromagnetic (EM) counterpart which, however, in many cases is expected to be faint and/or rapidly fading. Deep-wide optical survey telescopes as LSST, with their unique capability to characterize the faint variable sky over large areas, will play a crucial role in the detection of associated counterparts of GW sources.

The Istituto Nazionale di Astrofisica (INAF) is participating to a collaborative effort among the LIGO Scientific Collaboration, the European Gravitational Observatory and Virgo Collaboration (Virgo/EGO), to perform follow-up observations of GW candidate events with the sharing of proprietary information. Since May 2015, the GRAwitational Wave INAF TeAm GRAWITA is working to make possible prompt observational campaigns to GW alert from LIGO/Virgo collaboration (LVC). The GRAWITA follow-up procedure has been already tested on GW150914 by observing its large associated sky area and monitoring several associated EM candidates with multiwavelength facilities operating in the optical, near-mid IR and radio.

Poster

RAWITA: OBSERVING OFF-AXIS SHORT GAMMA RAY BURSTS IN THE LOCAL UNIVERSE

Giulia Stratta

Urbino University, IT

E-mail: giulia.stratta@uniurb.it

Short Gamma Ray Bursts (SGRBs) are among the best source candidates of simultaneous electromagnetic (EM) and gravitational waves (GWs) in the frequency range covered by the second generation laser interferometer detectors as Advanced LIGO and Advanced Virgo. So far,SGRBs have been detected only by observers with line of sight within the jet cone (on-axis). The off-axis configuration is, for geometrical reasons, a more likely scenario for joint GWs and electromagnetic detections.

In this work we perform the excercise of estimating a number of off-axis configurations that would make a sample of observed SGRBs detectable by present and future facilities if they were within the GW detector sensitivity horizon. We find that GRB 050709, GRB 051221, GRB 070714B, GRB 090426 and GRB 130603B (60% of our sample) could have been detected from an off-axis viewing angle of 2 to 4 times the jet cone aperture, up to 90° in one case, if they were at 200 Mpc. Thus, SGRBs with properties similar to this subsample, can be detected in both EM and GW with a rate ∼4 up to ∼16 times higher than the estimated on-axis rate within 200 Mpc, that is up to 3 simultaneous GW and EM detection per year from SGRBs.

Deep-wide optical survey telescopes as LSST, with their unique capability to characterize the faint variable sky over large areas, will play a crucial role in the detection and precise localization of off-axis SGRB. Coordinated multiwavelength follow-up campaigns as those performed by the GRAvitational Wave Inaf TeAm (GRAWITA) will allow to further characterize these sources maximizing the scientific output of the GW detection.

Poster

APPLICATION OF CEP ENGINES IN ASTRONOMY

Veljko Vujčić

Astronomical Observatory Belgrade, RS
E-mail: veljko@aob.rs

Complex Event Processing (CEP) methods and tools were developed for high-growth industries (such as finance, telecommunications, banking, medicine). They offer scalability which cannot be easily achieved through previous standard practices, loose coupling between event processing logic and the mainstream application code, and introduce languages with high level of abstraction for describing inference mechanisms (patterns). This poster discusses involvement of CEP in solving astronomical problems as well as potential architectural and technological solutions.

LIST OF PARTICIPANTS

Jovan Aleksić
jaleksic@aob.rs
Astronomical Observatory Belgrade, RS

Mark Allen
mark.allen@astro.unistra.fr
Observatoire Astronomique de Strasbourg, Université de Strasbourg, CNRS, UMR 7550, FR

George Angeli
GAngeli@lsst.org
LSST, USA

Pierre Astier
pierre.astier@in2p3.fr
LPNHE (Paris), FR

Peter Baumann
baumann@rasdaman.com
Jacobs University, DE

George Beckett
george.beckett@ed.ac.uk
Edinburgh University, UK

Dino Bektešević
ljetibo@gmail.com
Science and Society Synergy Institute, HR

Michal Bilek
michal.bilek@asu.cas.cz
Astronomical Institute of the Charles University in Prague, CZ

Giuseppe Bono
bono@roma2.infn.it
Dipartimento di Fisica Universita' di Roma tor Vergata, IT

James Bosch
jbosch@astro.princeton.edu
Princeton University, USA

Dominique Boutigny
boutigny@in2p3.fr
LAPP - CNRS/IN2P3, FR

Anthony Brown
brown@strw.leidenuniv.nl
Sterrewacht Leiden, Leiden University, NL

María Cebrián Renau
mcebrian@iac.es
Instituto de Astrofísica de Canarias, ES

Steve Chesley
steve.chesley@jpl.nasa.gov
Jet Propulsion Laboratory, USA

Maria-Rosa Cioni
mcioni@aip.de
Leibniz-Institute for Astrophysics Potsdam (AIP), DE

Gisella Clementini
gisella.clementini@oabo.inaf.it
INAF Osservatorio Astronomico Bologna, IT

Andrew Connolly
ajc@astro.washington.edu
University of Washington, USA

Bozena Czerny
bcz@cft.edu.pl
Center for Theoretical Physics, PL

Scott Daniel
scottvalscott@gmail.com
University of Washington, USA

Isabelle Delatouche

Janet Drew
j.drew@herts.ac.uk
University of Hertfordshire, UK

Patricia Eliason
PEliason@lsst.org
LSST Corporation, USA

Laurent Eyer
laurent.eyer@unige.ch
University of Geneva, CH

Merlin Fisher-Levine
merlin.fisherlevine@gmail.com
Brookhaven National Laboratory, USA

Wesley Fraser
wes.fraser@qub.ac.uk
Queen's University Belfast, UK

Mikael Granvik
mgranvik@iki.fi
University of Helsinki, FI

Alan Heavens
a.heavens@imperial.ac.uk
Imperial College London, UK

Nina Hernitschek
hernitschek@mpia.de
Max-Planck-Institut fuer Astronomy, Heidelberg, DE

Dragana Ilić
dilic@matf.bg.ac.rs
Department of Astronomy, Faculty of Mathematics, University of Belgrade, RS

Željko Ivezić
ZIvezic@lsst.org
University of Washington, USA

Darko Jevremović
darko@aob.rs
Astronomical Observatory Belgrade, RS

Milena Jovanović
milena@aob.rs
Astronomical Observatory Belgrade, RS

Mario Jurić
mjuric@astro.washington.edu
University of Washington, USA

Tomislav Jurkić
tjurkic@phy.uniri.hr
Department of Physics, University of Rijeka, HR

Monika I. Jurković
mojur@aob.rs
Astronomical Observatory Belgrade, RS

Steven Kahn
SKahn@lsst.org
LSST/SLAC/Stanford, USA

Sugata Kaviraj
s.kaviraj@herts.ac.uk
University of Hertfordshire, UK

Yana Khusanova
yana.khusanova@student.uibk.ac.at
University of Innsbruck, AT

Laszlo Kiss
kiss.laszlo@csfk.mta.hu
Konkoly Observatory, HU

Ognyan Kounchev
kounchev@gmx.de
Institute of Mathematics and Informatics BAN, BG

Andjelka Kovačević
andjelka@matf.bg.ac.rs
Department of Astronomy, Faculty of Mathematics, University of Belgrade, RS

Marek Kowalski
marek.kowalski@desy.de
Humboldt-University Berlin, DE

Nicolas Lodieu
nlodieu@iac.es
IAC, Tenerife, ES

Robert Lupton
rhl@astro.princeton.edu
Princeton University, USA

Miodrag Malović
office@malovic.in.rs
Innovation Center, Faculty of Technology and Metallurgy, University of Belgrade, RS

Bob Mann
rgm@roe.ac.uk
University of Edinburgh, UK

Sladjana Marčeta Mandić
sladjana.mandic@gmail.com
Department of Astronomy, Faculty of Mathematics, University of Belgrade, RS

Djordje Marković
djordje.markovic@bio.bg.ac.rs
Faculty of Biology, University of Belgrade, RS

Cristina Martinez-Lombilla
cml@iac.es
Instituto de Astrofísica de Canarias, ES

Nemanja Martinović
nmartinovic@aob.rs
Astronomical Observatory Belgrade, RS

Richard McMahon
rgm@ast.cam.ac.uk
University of Cambridge, UK

Tatjana Milovanov
t_milovanov@yahoo.com
Astronomical Observatory Belgrade, RS

Nenad Milovanović
nmilovanovic@aob.rs
Astronomical Observatory Belgrade, RS

Joe Mohr
jmohr@usm.lmu.de
LMU-Munich, DE

Carole Mundell
C.G.Mundell@bath.ac.uk
University of Bath, UK

Bob Nichol
bob.nichol@port.ac.uk
University of Portsmouth, UK

Aleksandra Nina
sandrast@ipb.ac.rs
Institute of Physics, Belgrade, Serbia, RS

Anita Osmer

Patrick Osmer
osmer.1@osu.edu
LSSTC & Ohio State University, USA

Hiranya Peiris
h.peiris@ucl.ac.uk
University College London, UK

Agnieszka Pollo
agnieszka.pollo@gmail.com
Jagiellonian University and National Centre for Nuclear Research, PL

Luka Č. Popović
lpopovic@aob.rs
Astronomical Observatory Belgrade, RS

Tijana Prodanović
prodanvc@df.uns.ac.rs
University of Novi Sad, RS

Denis Puy
Denis.Puy@umontpellier.fr
University of Montpellier, Laboratory Universe and Particles of Montpellier, FR

Kristina Racković Babić
rackovick@yahoo.com
Department of Astronomy, Faculty of Mathematics, University of Belgrade, RS

Nemanja Rakić
nemanja.rakic@unibl.rs
Faculty of Science, University of Banjaluka, Republic of Srpska, BA

Djordje Savić
djsavic@aob.rs
Astronomical Observatory Belgrade, RS

Nigel Sharp
nsharp@nsf.gov
US National Science Foundation, USA

Saša Simić
ssimic@kg.ac.rs
Department of Physics, Faculty of Sciences, RS

Zoran Simić
zsimic@aob.rs
Astronomical Observatory Belgrade, RS

Dominique Sluse
slusedominique@googlemail.com
University of Liege, BE

Marijana Smailagić
marijana@aob.rs
Astronomical Observatory Belgrade, RS

Vladimir Srećković
vlada@ipb.ac.rs
Institute of Physics, Belgrade, RS

Marko Stalevski
mstalevski@aob.rs
University of Chile, CL

Giulia Stratta
giulia.stratta@uniurb.it
Urbino University, IT

Robert Szabo
rszabo@konkoly.hu
Konkoly Observatory, MTA CSFK, HU

Sonia Giovanna Temporin
giovanna.temporin@uibk.ac.at
Institute for Astro- and Particle Physics, University of Innsbruck, AT

Milcho Tsvetkov
milcho.tsvetkov@gmail.com
Institute of Mathematics and Informatics, BAS, BG

Antonella Vallenari
antonella.vallenari@oapd.inaf.it
INAF, Padova, IT

Peter Vereš
veres@jpl.nasa.gov
Jet Propulsion Laboratory, USA

Dejan Vinković
dejan@iszd.hr
Science and Society Synergy Institute, HR

Veljko Vujčić
veljko@aob.rs
Astronomical Observatory Belgrade, RS

Lucianne Walkowicz
l.m.walkowicz@gmail.com
The Adler Planetarium, USA

Nicholas Walton
naw@ast.cam.ac.uk
Institute of Astronomy, University of Cambridge, UK

AUTHORS' INDEX

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