Varying Constants and Fundamental Cosmology
VARCOSMOFUN'16
12 – 17 September 2016, Szczecin, Poland

Conference Programme

Monday, September 12

08:00 **Registration**
Maritime University campus building, ul. Szczerbcowa 4

09:00 – 09:10 **Conference opening** Room 7
Main lecture hall (Room 7), 1st floor

09:10 – 10:05 **Jean-Philippe Uzan** Room 7
(45+10) Fundamental constants, gravitation and cosmology – recent developments

Fundamental constants play a central role in the laws of physics. Any detection of the variation of these constant would signal a violation of the Einstein equivalence principle, and thus the need to go beyond general relativity. After recalling the links between fundamental constants and theories of gravity, I will focus on recent developments to constrain their time variation, mostly concentrating on big-bang and stellar nucleosynthesis as well as the analysis of the observations by the Planck satellite. The connection with cosmology, in particular the physics of the dark sector and fine tuning issues will be discussed.

10:05 – 11:00 **João Magueijo** Room 7
(45+10) Varying constants, cosmology and the puzzle of quantum gravity

Varying constants theories in several guises may be essential for the resolution of a number of impasses in cosmology and quantum gravity. Perhaps the most radical of them all – varying c theories – may be the clue to extracting phenomenology from quantum gravity theories, finally rendering the field properly a branch of science. I will review this possibility, with particular emphasis on the issue of the generation of cosmic structure and primordial gravitational waves.

11:00 – 11:30 ***Coffee break*** *(30 min)*

11:30 – 12:30 **Ekkehard Peik** Room 7
(50+10) Search for New Physics with Atomic Clocks

The precision of atomic clocks improves at a rapid pace: While caesium clocks now reach relative uncertainties of a few 10^{-16}, several optical clocks based on different atoms and ions are now reported with systematic uncertainties in the low 10^{-18} range. The Yb^+ optical clock at PTB has recently reached this uncertainty, following Hans Dehmelt's seminal ideas of using a single trapped ion, laser cooling and the observation of quantum jumps as a spectroscopic signal, but based on an unusual reference transition (S-F electric octupole) and special Ramsey interrogation schemes that suppress systematic frequency shifts. The availability of highly precise clocks relying on different quantum systems allows for improved tests of fundamental physics, especially quantitative tests of relativity and searches for violations of the equivalence principle. The strong relativistic contributions to the transition energy and the high electronic angular momentum of the F-state make the Yb^+ optical clock an especially sensitive test case. In comparisons with a ^{87}Sr optical lattice clock at PTB we have performed improved tests for temporal variations of the fine structure constant and the proton-to-electron mass ratio, of coupling of α to gravity in the Solar potential and of violation of Lorentz invariance in the electron sector.

12:30 – 14:00 ***Lunch*** Room 4

	[VC-T] Room 7 **Varying constants – theory**		**[QC]** Room 6 **Quantum gravity and cosmology – Part I**		**[OC/GW]** Room 5 **Observational cosmology and gravitational waves**	
14:00 – 15:40	Rodger Thompson	(35+5)	Michael Heller	(20+5)	Signe Riemer-Sørensen	(25+5)
	Anastasia Borschevsky	(25+5)	Imanol Albarran	(20+5)	Iker Leanizbarrutia Alonso	(25+5)
	Adam Balcerzak	(25+5)	Mariam Bouhmadi-López	(20+5)	Adam Zadrożny	(25+5)
			Nick Kwidzinski	(20+5)		
15:40 – 16:10	***Coffee break*** *(30 min)*					
16:10 – 17:50	Hussain Gohar	(25+5)	Jakub Mielczarek	(20+5)	Martín López Corredoira	(25+5)
	Konrad Marosek	(25+5)	David Brizuela	(20+5)	Janusz Garecki	(25+5)
	Katarzyna Leszczyńska	(25+5)	Daniel Martín de Blas	(20+5)	Hristu Culeţu	(25+5)
			Tomasz Pawłowski	(20+5)		

19:00 **Welcome reception**
Restaurant "Zamkowa" in the Pomeranian Dukes' Castle, ul. Rycerska 3

Room 7 Varying constants – theory

Convener: **Mikhail Kozlov**

14:00 – 14:40	(35+5)	**Rodger Thompson** – The Relation Between Fundamental Constants and Particle Physics Parameters
14:40 – 15:10	(25+5)	**Anastasia Borschevsky** – Diatomic molecules as probes for variation of fundamental constants
15:10 – 15:40	(25+5)	**Adam Balcerzak** – Non-minimally coupled varying constants quantum cosmologies
15:40 – 16:10		***Coffee break*** *(30 min)*
16:10 – 16:40	(25+5)	**Hussain Gohar** – Varying constant theories from thermodynamics perspective
16:40 – 17:10	(25+5)	**Konrad Marosek** – Varying constants and cyclic universes
17:10 – 17:40	(25+5)	**Katarzyna Leszczyńska** – Varying constants quantum cosmology

Room 6 Quantum gravity and cosmology – Part I

Convener: **Mariam Bouhmadi-López**

14:00 – 14:25	(20+5)	**Michael Heller** – Synthetic approach to the singularity problem
14:25 – 14:50	(20+5)	**Imanol Albarran** – Cosmological perturbations in dark energy phantom models
14:50 – 15:15	(20+5)	**Mariam Bouhmadi-López** – Current status on dark energy singularities
15:15 – 15:40	(20+5)	**Nick Kwidzinski** – Classical and quantum cosmology of Born-Infeld type models
15:40 – 16:10		***Coffee break*** *(30 min)*
16:10 – 16:35	(20+5)	**Jakub Mielczarek** – Nonlinear Field Space Theory
16:35 – 17:00	(20+5)	**David Brizuela** – Effects from canonical quantum gravity for slow-roll inflationary models
17:00 – 17:25	(20+5)	**Daniel Martín de Blas** – Perturbation vacua and primordial power spectra in Loop Quantum Cosmology
17:25 – 17:50	(20+5)	**Tomasz Pawłowski** – Universe's memory and spontaneous coherence in loop quantum cosmology

Room 5 Observational cosmology and gravitational waves

Convener: **Vincenzo Fabrizio Cardone**

14:00 – 14:30	(25+5)	**Signe Riemer-Sørensen** – Nucleosynthesis predictions and high-precision deuterium measurements
14:30 – 15:00	(25+5)	**Iker Leanizbarrutia Alonso** – Analysing a forecast cosmological redshift drift
15:00 – 15:30	(25+5)	**Adam Zadrożny** – Searching for optical counterparts to gravitational wave events – and how it might be done by wide field surveys
15:30 – 16:10		***Coffee break*** *(40 min)*
16:10 – 16:40	(25+5)	**Martín López Corredoira** – Tests and problems of the standard model in Cosmology
16:40 – 17:10	(25+5)	**Janusz Garecki** – Energy and momentum transferred by gravitational waves
17:10 – 17:40	(25+5)	**Hristu Culeţu** – On a nonlinear gravitational wave

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Tuesday, September 13

09:00 – 10:00 (50+10) — **Hidetoshi Katori** — Room 7

Frequency ratios of optical lattice clocks at the 17th decimal place

Optical lattice clocks benefit from a low quantum-projection noise by simultaneously interrogating a large number of atoms, which are trapped in an optical lattice tuned to the "magic wavelength" to largely cancel out light shift perturbation in the clock transition. About a thousand atoms enable the clocks to achieve 10^{-18} instability in a few hours of operation, allowing intensive investigation and control of systematic uncertainties. It is now the uncertainty of the SI second (~ 10^{-16}) itself that restricts the measurement of the absolute frequencies of such optical clocks. Direct comparisons of optical clocks are, therefore, the only way to investigate and utilize their superb performance beyond the SI second. In this presentation, we report on frequency comparisons of optical lattice clocks with neutral strontium (^{87}Sr), ytterbium (^{171}Yb) and mercury (^{199}Hg) atoms. By referencing cryogenic Sr clocks, we determine frequency ratios, ν_{Yb}/ν_{Sr} and ν_{Hg}/ν_{Sr}, of a cryogenic Yb clock and a Hg clock with uncertainty at the mid 10^{-17}. Such ratios provide an access to search for temporal variation of the fundamental constants. We also present remote comparisons between cryogenic Sr clocks located at RIKEN and the University of Tokyo over a 30-km-long phase-stabilized fiber link. The gravitational red shift $\Delta\nu/\nu_0 \approx 1.1 \times 10^{-18}\ \Delta h\ \mathrm{cm}^{-1}$ reads out the height difference of Δh ~ 15 m between the two clocks with uncertainty of 5 cm, which demonstrates a step towards relativistic geodesy. We also mention our ongoing experiments that reduce clock uncertainty to 10^{-19} by applying "operational magic frequency," where light shifts due to dipole, multipolar, and hyper-polarizability effects effectively cancel out for a certain range of optical lattice intensity.

10:00 – 11:00 (50+10) — **Wim Ubachs** — Room 7

Search for varying constants and new physics from molecular hydrogen

The spectroscopy of molecular hydrogen can be used for a search into physics beyond the Standard Model. Differences between the absorption spectra of the Lyman and Werner bands of H_2 as observed at high redshift and those measured in the laboratory can be interpreted in terms of possible variations of the proton-electron mass ratio $\mu = m_p/m_e$ over cosmological history. Investigation of some ten of such absorbers in the redshift range $z = 2.0 - 4.2$ yields a constraint of $|\Delta\mu/\mu| < 5 \times 10^{-6}$ at 3σ. Observation of H_2 from the photospheres of white dwarf stars inside our Galaxy delivers a constraint of similar magnitude on a dependence of μ on a gravitational potential 104 times as strong as on the Earth's surface. While such astronomical studies aim at finding quintessence in an indirect manner, laboratory precision measurements target such additional quantum fields in a direct manner. Laser-based precision measurements of dissociation energies, vibrational splittings and rotational level energies in H_2 molecules and their deuterated isotopomers HD and D_2 produce values for the rovibrational binding energies fully consistent with quantum ab initio calculations including relativistic and quantum electrodynamical (QED) effects. Similarly, precision measurements of high-overtone vibrational transitions of HD^+ ions, also result in transition frequencies fully consistent with calculations including QED corrections. These comprehensive results of laboratory precision measurements on neutral and ionic hydrogen molecules can be interpreted to set bounds on the existence of possible fifth forces and of higher dimensions, phenomena describing physics beyond the Standard Model.

11:00 – 11:30 ***Coffee break*** *(30 min)*

11:30 – 12:30 (50+10) — **Julian Berengut** — Room 7

Measuring α-variation using highly-charged ions: clocks, calculations and astrophysics

Several recent proposals to measure α-variation use highly-charged ions, in which the effects of a possible variation are enhanced. These systems include potential new clocks that are predicted to have extraordinarily high accuracy. In systems where the transitions are available due to level crossings, the clocks can have extremely high sensitivity to variation of the fine-structure constant α, potentially improving current limits on time-variation of α by up to two orders-of-magnitude. The experimental spectroscopy of one such candidate, the Ir17+ ion which has two holes in the otherwise closed 4f14 5s2 valence shells, has shown that current theoretical methods have severe limitations in accurately describing the spectrum. That study included (along with the experimental spectrum) the results of several calculations including different variants of configuration interaction (CI), multiconfigurational Dirac-Fock, and Fock-space coupled cluster. None of the theories tested were able to unambiguously identify the entire observed spectrum. Furthermore many existing methods of calculation – such as the combined configuration interaction and many-body perturbation theory (CI+MBPT), correlation potential methods, and coupled-cluster methods – are designed to work well in one or two-valence-electron atoms and particularly in near-neutral systems. We have developed an ab initio method of calculating atomic spectra and properties in complicated systems, such as HCIs and particularly where electron-holes play an important role. Based on the CI +MBPT method, we have implemented Wick contractions numerically in AMBiT allowing the inclusion of configurations with arbitrary numbers of valence holes and electrons. As a first test case, we have performed calculations of spectra and sensitivity to α-variation for the Hg+ ion, where the clock transition 6s to 5d−1 6s2 has been compared with an Al + clock to get the best current limit on time-variation of α. We present results of the full CI+MBPT method with holes, and updated limits on time-variation of α based on the existing experiment. The enhanced sensitivity to α-variation of highly-charged ions is also exploited in astrophysical measurements of metal lines in the spectra of white-dwarf stars. These are used to probe the dependence of α on a strong gravitational field. While the FeV and NiV ions used in this study are less highly-charged, many of the limitations in the accuracy of calculations are common to the clock HCIs.

12:30 – 14:00 ***Lunch*** — Room 4

	[VC-E] Room 7 **Varying constants – laboratory experiments**		**[QE]** Room 6 **Quantum entanglement and many-worlds interpretation**		**[DE]** Room 5 **Dark energy**	
14:00 – 15:40	Jocelyne Guéna	(25+5)	Sugumi Kanno	(30+5)	Antonio De Felice	(30+5)
	Lykourgos Bougas	(25+5)	Jan Pieter van der Schaar	(30+5)	Ryotaro Kase	(30+5)
	Piet Schmidt	(25+5)	Jiro Soda	(25+5)	Tetsuya Hara	(25+5)
15:40 – 16:10	***Coffee break*** *(30 min)*					
16:10 – 17:50	Piotr Wcisło	(25+5)	Will Kinney	(30+5)	João Morais	(20+5)
			Nadia Bolis	(30+5)	Reinoud Slagter	(20+5)
			Sayantan Choudhury	(25+5)	Irina Dymnikova	(20+5)
					Anna Dobosz	(20+5)

Room 7 Varying constants – laboratory experiments

Convener: **Ekkehard Peik**

14:00 – 14:30	(25+5)	**Jocelyne Guéna** – Searching for variations of fundamental constants and dark matter using an atomic clock ensemble
14:30 – 15:00	(25+5)	**Lykourgos Bougas** – Tabletop experiments using atomic dysprosium and ytterbium for tests of fundamental physics
15:00 – 15:30	(25+5)	**Piet Schmidt** – Towards quantum logic spectroscopy of molecular ions
15:30 – 16:10		***Coffee break*** *(40 min)*
16:10 – 16:40	(25+5)	**Piotr Wcisło** – Constraint on transient variations of fine-structure constants with optical atomic clocks

Room 6 Quantum entanglement and many-worlds interpretation

Convener: **Sugumi Kanno**

14:00 – 14:35	(30+5)	**Sugumi Kanno** – Cosmological implications of quantum entanglement in the multiverse
14:35 – 15:10	(30+5)	**Jan Pieter van der Schaar** – Vacua and correlators on hyperbolic de Sitter sections
15:10 – 15:40	(25+5)	**Jiro Soda** – Quantum Discord in de Sitter spacetime
15:40 – 16:10		***Coffee break*** *(30 min)*
16:10 – 16:45	(30+5)	**Will Kinney** – Limits on Entanglement Effects in the String Landscape from Planck and BICEP/Keck Data
16:45 – 17:20	(30+5)	**Nadia Bolis** – Observational Consequences of Scalar-tensor Entanglement During Inflation
17:20 – 17:50	(25+5)	**Sayantan Choudhury** – Bell violation in the Sky

Room 5 Dark energy

Convener: **Shinji Tsujikawa**

14:00 – 14:35	(30+5)	**Antonio De Felice** – Phenomenology of minimal theory of massive gravity
14:35 – 15:10	(30+5)	**Ryotaro Kase** – Effective gravitational couplings for cosmological perturbations in generalized Proca theories
15:10 – 15:40	(25+5)	**Tetsuya Hara** – Thawing model seems to be preferable for dark energy potential in the quintessence scenario
15:40 – 16:10		***Coffee break*** *(30 min)*
16:10 – 16:35	(20+5)	**João Morais** – 3-form cosmology: phantom behavior, singularities and interactions
16:35 – 17:00	(20+5)	**Reinoud Slagter** – NonLinear Gravitational Waves as Dark Energy in Warped Spacetimes
17:00 – 17:25	(20+5)	**Irina Dymnikova** – Vacuum dark energy and spacetime symmetry
17:25 – 17:50	(20+5)	**Anna Dobosz** – Lemaître class dark energy model for relaxing cosmological constant

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Wednesday, September 14

09:00 – 10:00 (50+10) **Andrzej Królak** — Room 7

Observations of gravitational waves from binary black hole mergers

Detection of gravitational waves from mergers of two black holes is one of the greatest discoveries of this century. It will open a new window on the Universe. I shall describe observations of these signals in the data of LIGO detectors by consortium of LIGO Scientific Collaboration and Virgo Collaboration. I shall present several aspects of this discovery: gravitational wave detectors, signal modeling and data analysis. I shall mention the follow-up observations of this event by radio, optical, near-infrared, X-ray, and gamma-ray wavelengths with ground- and space-based facilities. I shall describe consequences of this result for physics of fundamental interactions.

10:00 – 11:00 (50+10) **David Marsh** — Room 7

Varying constants and the cosmological constant problem

I will discuss how quantum mechanics makes the vacuum energy very sensitive to the values of physical parameters and how this exacerbates the cosmological constant problem in theories with varying 'constants'. Models of "interacting dark energy" in which the masses of dark matter states depend on the dark energy sector provide a striking example of this: in some models the finetuning of the vacuum energy is exacerbated from one part in 10^{50} to one part in 10^(10^10). I will discuss how such models are too fine-tuned to be compatible with an anthropic solution to the cosmological constant problem in the presently understood string theory landscape. Such models admit distinctive observational signatures that may be detected by future experiments, hence providing an opportunity to observationally rule out the anthropic landscape solution of the cosmological constant problem in any theory with a finite number of vacua.

11:00 – 12:00 ***Early lunch and distribution of the lunch packs for the excursion*** — Room 4

Excursion to the Max Planck Institute for Plasma Physics in Greifswald

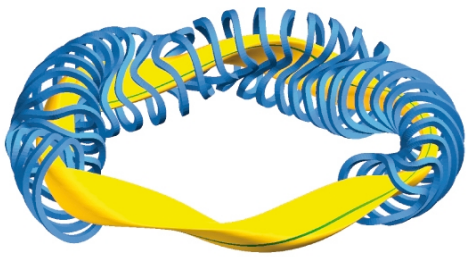
You will see the stellarator Wendelstein 7-X, which is now the largest device for fusion experiments in the world.

12:00 – 14:00 Bus ride to Greifswald

14:00 – 16:00 **Visit of the Max Planck Institute** with an **introductory presentation** followed by a **guided tour** in 4 groups of up to 20 people

16:00 – 18:30 **Visit of the Old Town in Greifswald** (Walk along *"Lange Straße"* until you reach the central Market Square.)

18:30 – 20:30 Bus ride from Greifswald back to Szczecin



By Max Planck Institute for Plasma Physics / CC BY 3.0

Excursion to the Historical Technical Museum in Peenemünde

You will visit the former military test site, where the first V-2 rocket was launched up to 100 km above the ground in 1942, which further led to the construction of the American Saturn-type rockets.

12:00 – 14:30 Bus ride to Peenemünde

14:30 – 18:00 **Guided tour (1.5 h)** followed by a visit of the museum and its surroundings **on your own** – including the possibility to take the **elevator to the roof of the museum** (*cost:* 1 € in coins to be payed at a ticket machine at the elevator)

18:00 – 20:30 Bus ride from Peenemünde back to Szczecin

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Thursday, September 15

09:00 – 10:00 (50+10) — **John Webb** — Room 7

Spacetime variations of the varying alpha: The first 1000 high-precision measurements

We are preparing a large sample of high-precision varying α measurements using quasar spectra. The measurements are being made using the new automated AI methodology described in arXiv:1606.07393 which eliminates any important human bias. A detailed study of long-range wavelength distortions in UVES/VLT and HIRES/Keck samples will also be described. I will show that such distortions are indeed present, but do not explain the tentative spatial variation of α, contrary to a previous claim. Moreover, long range wavelength distortions can be accurately measured using the quasar spectra themselves and hence can be removed from the final set of α measurements.

10:00 – 11:00 (50+10) — **Michael Murphy** — Room 7

New, precise and reliable quasar absorption limits on alpha-variation

Previous evidence for time and space variations in the fine-structure constant (alpha) emerged from large samples of quasar spectra observed with the Very Large Telescope and Keck telescope. I will first review this evidence in light of our work that identified systematic wavelength calibration errors in these telescopes. These errors are subtle, complex and still not fully understood; they clearly change with time, making it difficult to estimate the detailed effect they had on the quasar spectra. Nevertheless, I will argue that they are likely to explain the previous evidence for variations in alpha, and at least substantially weaken that evidence. Secondly, I will describe new observations and measurements which are corrected for, or are insensitive to, these calibration errors. In particular, I will report 11 new such measurements which, combined, constrain the relative deviation in alpha to be $\Delta\alpha/\alpha=0.4 \pm 1.7$ parts-per-million from the current laboratory value at redshifts 1.0 – 2.4 (look-back times of 7.8 – 11 billion years). This is consistent with no variation in alpha at a precision level comparable to that of the two large quasar samples. However, the particular distribution of these quasars on the sky precludes a strong test of possible evidence variation in alpha across the sky in those large samples (ignoring the calibration errors above). I will report on progress towards several new measurements that, combined with those reported here, should enable such a test.

11:00 – 11:30 — ***Coffee break*** *(30 min)*

11:30 – 12:30 (50+10) — **Carlos Martins** — Room 7

Fundamental cosmology in the E-ELT era

The observational evidence for the recent acceleration of the universe demonstrates that canonical theories of cosmology and particle physics are incomplete (and possibly incorrect) and that new physics is out there, waiting to be discovered. The most fundamental task for the next generation of astrophysical facilities is to search for, identify and ultimately characterize this new physics. I will highlight the E-ELT's key role in this quest. After a short overview of theoretical motivations for new physics, the discussion will focus on precision spectroscopy tests of fundamental physics and cosmology. I will summarize the current status of these tests, discuss a classification of physically motivated models, and present some forecasts of the improvements that the E-ELT will enable (comparing them to ESPRESSO when appropriate). Time permitting I will also briefly comment on synergies with other E-ELT instruments, and with other facilities such as ALMA and Euclid.

12:30 – 14:00 — ***Lunch*** — Room 4

	[VC-O] Room 5 **Varying constants – astronomical observations**		**[INF/DM]** Room 6 **Inflation, early universe and dark matter**	
14:00 – 15:40	Vincent Dumont	(20+5)	Iberê Kuntz	(25+5)
	Srđan Kotuš	(20+5)	Łukasz Nakonieczny	(25+5)
	Matthew Bainbridge	(20+5)	Chris Longden	(25+5)
	Ana Catarina Leite	(20+5)		
15:40 – 16:10	***Coffee break*** *(30 min)*			
16:10 – 17:50	Jiting Hu	(20+5)	Debottam Nandi	(25+5)
	Ivan De Martino	(20+5)	Arghya Choudhury	(25+5)
	Vincenzo Salzano	(20+5)	Sajid Ali	(25+5)
	Lijing Shao	(20+5)		

18:30 — **Public lecture by Paul C. W. Davies** — Room 7

"Are We Alone in the Universe?"

20:30 — **Conference dinner**

Restaurant "Dzika Gęś", plac Orła Białego 1

Room 5 Varying constants – astronomical observations

Convener: Michael Murphy

14:00 – 14:25	(20+5)	**Vincent Dumont** – Impact of long-range wavelength-scale distortion on fine-structure constant measurements
14:25 – 14:50	(20+5)	**Srđan Kotuš** – High-precision limit on variation in the fine-structure constant from a single quasar absorption system
14:50 – 15:15	(20+5)	**Matthew Bainbridge** – Artificial intelligence applied to the automated analysis of absorption spectra
15:15 – 15:40	(20+5)	**Ana Catarina Leite** – Dark energy constraints from ESPRESSO tests of the stability of fundamental couplings
15:40 – 16:10		***Coffee break*** *(30 min)*
16:10 – 16:35	(20+5)	**Jiting Hu** – Different laws of nature in strong gravitational fields? Study dependence of fine-structure constant on gravitational potential by using white-dwarf spectra
16:35 – 17:00	(20+5)	**Ivan De Martino** – New constraints on spatial variations of the fine structure constant from clusters of galaxies
17:00 – 17:25	(20+5)	**Vincenzo Salzano** – Recovering a redshift-extended VSL signal from galaxy surveys
17:25 – 17:50	(20+5)	**Lijing Shao** – Tests of local Lorentz invariance of post-Newtonian gravity

Room 6 Inflation, early universe and dark matter

Conveners: Mark Hindmarsh, Enrico Maria Sessolo

14:00 – 14:30	(25+5)	**Iberê Kuntz** – Higgs Starobinsky inflation
14:30 – 15:00	(25+5)	**Łukasz Nakonieczny** – Running of the Higgs quartic coupling, gravity and the stability of the Higgs effective potential
15:00 – 15:30	(25+5)	**Chris Longden** – Running of the Running and Entropy Perturbations During Inflation
15:30 – 16:10		***Coffee break*** *(40 min)*
16:10 – 16:40	(25+5)	**Debottam Nandi** – Complete Hamiltonian analysis of cosmological perturbations at all orders
16:40 – 17:10	(25+5)	**Arghya Choudhury** – Less-simplified models of dark matter for direct detection and the LHC
17:10 – 17:40	(25+5)	**Sajid Ali** – Cosmological Isotropization from Symmetry Point of View

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Friday, September 16

09:00 – 10:00 (50+10) — **Carsten van de Bruck** — Room 7

Disformal electrodynamics: from varying alpha to vacuum Cherenkov radiation

In scalar-tensor theories the gravitational sector is extended by including an additional scalar degree of freedom. The most general metric that can be built in such a theory includes disformal terms so that standard model fields move on a metric which is the sum of the space time metric and a tensor constructed from first derivatives of the scalar. In such a theory gravitational waves and photons can propagate at different speeds, and these can in turn be different from the maximum speed limit for matter particles. As I will discuss, disformal couplings can cause charged particles to emit Cherenkov radiation and bremsstrahlung apparently in vacuum, depending on the background evolution of the scalar field. In addition, the fine structure constant becomes time-dependent. I will discuss the implications of such a model in detail and discuss the constraints that arise for models of dark energy with disformal couplings.

10:00 – 11:00 (50+10) — **John Moffat** — Room 7

Dark Matter, Dark Energy, Gravitational Waves and Black Holes

The standard model of cosmology features three key theoretical paradigms: 1) Inflation, 2) Dark Matter, 3) Dark Energy (accelerated expansion of the universe). Inflation has severe fine-tuning problems and the need for eternal inflation and a multiverse. The alternative model Variable Speed of Light Cosmology (VSL) can avoid these problems and fit available observational data. The CMB is described with remarkable success by the standard concordance model, based on six parameters. Of these the dark matter Ω_m and dark energy Ω_Λ parameters are poorly understood. Dark matter particle candidates have not been conclusively observed in the present universe in laboratory and satellite experiments. Dark Energy can be explained by the cosmological constant at the price of a huge fine-tuning problem. Moreover, the assumptions of a homogeneous and isotropic LFRW universe and the Copernican principle have not been fully tested. A modified gravitation (MOG) theory will be reviewed that can explain the lack of direct non-gravitational detection of Dark Matter in the present universe and its ability to fit galaxy and galaxy cluster data will be described. The conservative explanation of the accelerated expansion of the universe based on voids will be reviewed. The LIGO-Virgo experimental detection of gravitational waves and Event Horizon Telescope imaging of the supermassive black holes Sagittarius A* and M37 will be able to distinguish MOG black holes from the Schwarzschild and Kerr black holes.

11:00 – 11:30 ***Coffee break*** *(30 min)*

11:30 – 12:30 (50+10) — **Laura Mersini-Houghton** — Room 7

Predictions from the Quantum Multiverse

In trying to understand the selection of the initial state of the universe, physics is experiencing a paradigm shift on the last decade. A multiverse extension of the standard model of cosmology is now a promising and active direction of research. I will provide a brief introduction of various efforts in extending cosmic inflation to a multiverse origin. I will then describe in some detail how we can derive, instead of postulating, the selection of the initial state of the universe in the context of my theory of the quantum multiverse; and, how, information about the origin of our universe can be revealed and tested with current astrophysical data.

12:30 – 14:00 ***Lunch*** — Room 4

	[MG] Room 7 **Modifications of gravity**		**[MV]** Room 6 **Multiverse**	
14:00 – 15:40	Nelson Nunes	(30+5)	Wonwoo Lee	(30+5)
	Shinji Tsujikawa	(30+5)	Marco Vojinović	(30+5)
	Jose Beltrán Jiménez	(25+5)	Salvador Robles-Pérez	(25+5)

15:40 – 16:10 ***Coffee break*** *(30 min)*

	[MG] Room 7 **Modifications of gravity**		**[QC]** Room 6 **Quantum gravity and cosmology – Part II**	
16:10 – 17:50	Laur Järv	(25+5)	Ana Alonso Serrano	(20+5)
	Masaaki Morita	(25+5)	Tomasz Miller	(20+5)
	Martín López Corredoira	(15+5)	Michał Eckstein	(20+5)
			Jerzy Król	(20+5)

Room 7 Modifications of gravity

Convener: **Jose Beltrán Jiménez**

14:00 – 14:35	(30+5)	**Nelson Nunes** – Cosmology of the de Sitter Horndeski models
14:35 – 15:10	(30+5)	**Shinji Tsujikawa** – Cosmology in generalized Proca theories and beyond
15:10 – 15:40	(25+5)	**Jose Beltrán Jiménez** – Modified gravity with vector distortion and cosmological applications
15:40 – 16:10		***Coffee break*** *(30 min)*
16:10 – 16:40	(25+5)	**Laur Järv** – Effective gravitational "constant" in scalar-(curvature)tensor and scalar-torsion gravities
16:40 – 17:10	(25+5)	**Masaaki Morita** – Post-Newtonian parameter in f(R) gravity
17:10 – 17:30	(15+5)	**Martín López Corredoira** – The Number of Tidal Dwarf Satellite Galaxies in Dependence of Bulge Index

Room 6 Multiverse

Convener: **Salvador Robles-Pérez**

14:00 – 14:35	(30+5)	**Wonwoo Lee** – The false vacuum bubble as the creation of our universe
14:35 – 15:10	(30+5)	**Marco Vojinović** – The cosmological constant problem in piecewise-linear models of quantum gravity
15:10 – 15:40	(25+5)	**Salvador Robles-Pérez** – Observational consequences of an interacting multiverse
15:40 – 16:10		***Coffee break*** *(30 min)*

Room 6 Quantum gravity and cosmology – Part II

Convener: **Mariam Bouhmadi-López**

16:10 – 16:35	(20+5)	**Ana Alonso Serrano** – Entropy/information flux in Hawking radiation
16:35 – 17:00	(20+5)	**Tomasz Miller** – Causality for nonlocal phenomena
17:00 – 17:25	(20+5)	**Michał Eckstein** – Causality in "noncommutative spacetimes"
17:25 – 17:50	(20+5)	**Jerzy Król** – From quantum regime to cosmology via forcing and 4-smoothness

Varying Constants and Fundamental Cosmology
VARCOSMOFUN'16
12 – 17 September 2016, Szczecin, Poland

Conference Programme

Saturday, September 17

Philosophy and cutting edge of physics and cosmology

Convener: Mariusz P. Dabrowski

09:30 – 10:30 (50+10) **Krzysztof Meissner** — Room 7

Plato and Modern Physics

The talk is devoted to the discussion why modern fundamental physics is closer to the objective idealism of Plato than to the Aristotelian empiricism, after more than 2 thousand years of the domination of the latter in classical physics.

10:30 – 11:30 (50+10) **Paul C. W. Davies** — Room 7

Where do the laws of physics come from?

Since the time of Newton, the laws of physics have generally been regarded as absolute, universal, eternal and immutable. In the era of modern cosmology, early versions of the big bang theory assumed the laws were magically imprinted on the universe at the moment of its origin. Quantum cosmology, however, requires the laws to transcend the physical universe, while eternal inflation cosmology appeals to immutable meta-laws in a multiverse. Some cosmological theories renounce the notion of fixed laws altogether. Thus the status of the laws remains unclear and offers plenty of scope for misunderstanding and confusion. As a result, most physicists and cosmologists shrug aside the question of the source of the laws as lying outside the scope of science. I shall argue that the nature and origin of physical laws is a proper subject for scientific scrutiny and should not be summarily dismissed.

11:30 – 12:00 ***Coffee break*** *(30 min)*

12:00 – 12:30 (25+5) **Thomas Naumann** — Room 7

Do we live in the Best of all Worlds? – The fine tuning of the constants of Nature

On the occasion of the 300. anniversary of the death of G. W. Leibniz Einstein once said: "What really interests me is whether God could have created the world any differently." Our existence depends on a variety of constants which appear to be extremely fine tuned to allow for the existence of Life. These include the number of spatial dimensions, the strengths of the forces, the masses of the particles, the composition of the Universe and others. On the occasion of Leibniz' anniversary we discuss the question of whether we live in the "Best of all Worlds". The hypothesis of a multiverse could explain the mysterious fine tuning of so many fundamental quantities. Anthropic arguments are critically reviewed.

12:30 – 13:30 (50+10) **Michael Heller** — Room 7

How to justify the history of the universe?

The laws of physics not only allow for, but also enforce, in a sense, the origin of structures, even of such complex structures as living organisms. However, they mercilessly watch the balance: the grow must remain in agreement with the second law of thermodynamics – everything has to tend to the thermodynamical equilibrium, that is to say to the thermal death. Even the most stable structures must finally surrender to the statistical chaos. Physical evil: suffering, death, decay, find they raison d'etre in the structure of the Universe. They are a price for the very possibility of life. But what about moral evil when, for instance, a human being, making use of a physical evil destroys another human being? Moral evil appeared in the history of the Universe together with a being able to choose between good and bad. Before that there existed physical evil but the Universe was morally innocent. The existence of moral evil does not find its raison d'etre in physical laws. It transcends physics. Among various attempts to answer Leibniz's question "Why is there something rather than nothing?" there is one, especially rich in consequences. It claims that something exists because it is good. This is an echo of Plato's "the good and right … hold and bring things together" (Phaedo). In this perspective, existence and goodness are interchangeable (esse and bonum convertuntur). If goodness justifies existence then it also justifies rationality since everything that exists is implacably rational. It follows that evil is irrational and as such it cannot be rationally justified. This gap in rationality is tolerated since the Universe with evil and freedom (to make evil) is supposedly better than the Universe without evil and without freedom. This story is told on canvas of a cosmological scenario.

13:30 – 14:00 **Closing of the conference** — Room 7