

The Research Group
Theoretical Physics

has the honor to invite you to the public defense of the PhD thesis of
Vincent Luyten
to obtain the degree of Doctor of Sciences

Title of the PhD thesis:

**Non-linear dynamics in anti-de Sitter space and quantum chaos
in spin chains**

Promotor:

Prof. Ben Craps

Co-promotor:

Prof. Oleg Evnin

The defence will take place on

Tuesday October 15 2019 at 16h00

in Auditorium D.2.01 at the Campus Humanities,
Sciences and Engineering of the Vrije
Universiteit Brussel, Pleinlaan 2 - 1050 Elsene,
and will be followed by a reception.

Members of the jury:

Prof. Alexander Sevrin (chairman)
Prof. Freya Blekman (secretary)
Prof. Anne Dooms (VUB)
Prof. Frank Ferrari (ULB)
Prof. Chethan Krishnan
(Indian Institute of Science)

Curriculum vitae

Vincent Luyten obtained a Masters degree in Physics with greatest distinction from the Universiteit Antwerpen (UA) in 2015. He subsequently started a Ph.D. in theoretical physics at the Vrije Universiteit Brussel (VUB), focused on two main strands: solutions of mathematical physics equations inspired by stability problems in general relativity, and quantum chaos. This research resulted in two peer reviewed papers, published in international journals, and was presented at an international conference. He conducted research visits to Chulalongkorn University, Bangkok. During his time at VUB he was also involved in science education, supervising the exercises of two courses and mentoring two students during their bachelor projects.

Abstract of the PhD research

All of the research in this PhD is unified under the theme “small changes with big consequences”. It decouples in two separate strands of inquiry, the study of equations inspired by the question of stability of a certain spacetime in general relativity, and quantum chaos.

In general relativity gravity is described by the curvature of the spacetime in which particles move, as opposed to a force acting between the particles, as in the previous, Newtonian theory. Particles then move along a generalization of “straight lines” in this curved spacetime. The trajectory of e.g. the Earth around the Sun, is then not due to a force of the Sun on the Earth, but rather because the Earth moves along a “straight line”, in a spacetime which is curved due to the Sun, which ends up in the elliptic orbit we observe. The theory then requires an equation which tells us how spacetime will curve, for a given matter and energy content present in the spacetime (like the Sun). This is provided to us by Einstein’s equations. Some of the most basic curved spacetimes are then the ones for which there is no matter present, i.e. the spacetime is vacuum. In case this vacuum has negative energy density the resulting curved spacetime is called Anti-de Sitter spacetime (AdS). As with any spacetime, one can then ask if AdS is stable. Upon adding an arbitrarily small amount of matter in the spacetime it is no longer vacuum and hence the resulting spacetime is no longer exactly AdS. There are then two possibilities: if the new spacetime remains close to AdS for all times we say AdS is stable, if the new spacetime is very different from AdS, technically this means a black hole forms after a certain time, we say AdS is unstable. Whether AdS is stable or not remains an open question.

By applying perturbation theory to a toy model of an equation describing the evolution of this AdS-with-matter system, we found a simplified equation we call the conformal flow equation. We showed properties and found solutions of this equation. In nature’s inimitable way, there turn out to be very different physical systems whose equation describing their evolution is very similar mathematically to the conformal flow equation. The same solution techniques can hence be applied to these equations. We motivated the study of flow equations by discussing how they are part of a family of equations which show up in many different parts of mathematical physics.

In a separate line of research we consider quantum chaos. For classical mechanics systems there is a clear definition of a system being chaotic. For example, it displays the so-called butterfly effect. Popularly this is often described as a butterfly clapping its wings in Asia for example resulting in a tornado in America after a certain time. Technically this means that two particles whose evolution starts at nearly-identical initial conditions move apart exponentially in phase-space. On the other hand a similar definition of quantum chaos is still lacking. There exist proposals for a quantum mechanical version of this butterfly effect, which would be the exponential growth of the quantum mechanical analog of the distance in phase-space, the commutator squared. We studied this quantity for a chaotic quantum system, a 1d Ising spin chain with external magnetic fields applied. We found that the commutator squared does not display exponential growth in the fully quantum regime and showed that it does appear when taking the classical limit of this quantum system.