CSC-RUB PhD Project Proposal

Title: Cosmological measurements of weak gravitational lensing from ground and space

Sector of research: Dr.rer.nat.

Degree awarded: Astronomy

Keywords: Cosmology, weak gravitational lensing, cosmic shear, wide-field imaging surveys, multi-band photometry, photometric redshifts, galaxy shape measurements, cosmological modelling

Supervisors of PhD project:

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Prof. Dr. Ralf-Jürgen Dettmar, Chair of Astronomy, Astronomical Institute, Faculty of Physics and Astronomy

Research focus of supervisor: My research at RUB and the GCCL is focussed on observational cosmology, in particular high-precision measurements of the weak gravitational lensing effect of the large-scale structure of the Universe - also called cosmic shear - with the best available ground- and soon space-based wide-field imaging data sets, such as the Kilo-Degree Survey (KiDS), the ESA/NASA Euclid space mission, as well as the Chinese Space Station Optical Survey (CSS-OS) conducted with the Chinese Space Station Telescope (CSST). One of the biggest questions to be answered with such measurements is whether these cosmic shear measurements are in tension with measurements from the cosmic microwave background conducted with the Planck satellite. If confirmed this would potentially lead to a revolution in our understanding of the Universe as a whole. In order to get a robust answer to this question we work on all parts of the analysis of cosmic shear surveys, i.e. the data reduction, multi-band photometry, photometric redshifts, shape measurements, weak lensing observables, their covariance matrices, cosmological modelling, and inference of cosmological parameters.

Publications: In the past five years, I have published 145 papers (112 of which in refereed journals) with a total number of 5259 citations and an h-index of 39. Five examples of important papers related to the proposed PhD project are:

1. Hildebrandt, H., Viola, M., Heymans, C., et al. 2017, "KiDS-450: cosmological parameter constraints from tomographic weak gravitational lensing", Monthly Notices of the Royal Astronomical Society 465, 1454
2. Hildebrandt, H., Köhlinger, F., van den Busch, J. L., et al. 2020, "KiDS+VIKING-450: Cosmic shear tomography with optical and infrared data", Astronomy and Astrophysics 633, A69
3. Joudaki, S., Hildebrandt, H., Traykova, D., et al. 2020, "KiDS+VIKING-450 and DES-Y1 combined: Cosmology with cosmic shear", Astronomy and Astrophysics 638, L1
4. Wright, Angus H., Hildebrandt, Hendrik, Kuijken, Konrad, et al. 2019, "KiDS+VIKING-450: A new combined optical and near-infrared dataset for cosmology and astrophysics", Astronomy and Astrophysics 632, A34

5. Shan, HuanYuan, Liu, Xiangkun, Hildebrandt, Hendrik, et al. 2018, "KiDS-450: cosmological constraints from weak lensing peak statistics - I. Inference from analytical prediction of high signal-to-noise ratio convergence peaks", Monthly Notices of the Royal Astronomical Society 474, 1116

Summary of research plan

Background: The cosmological standard model has been in place for more than two decades, successfully explaining almost all cosmological observations of increasing precision. Recently, two tensions between early- and late-Universe measurements have surfaced that cannot be explained in the framework of the standard model. One of these tensions, which has reached a level of ~3σ, is a mismatch in the clustering amplitude of matter as measured by the Planck satellite and by weak gravitational lensing experiments. It is possible that this tension (and the other one related to the Hubble constant) can be resolved by a better understanding of the mysterious dark energy that seems to dominate the energy density of our Universe.

Study objective: The candidate will be trained to conduct highly precise and accurate measurements of the cosmic shear effect learning about all relevant parts of the analysis. Besides this broad overview, the candidate will specialise in one of the technical aspects, e.g. the calibration of photometric redshifts, to become a world-leading expert in this niche. This knowledge will be applied to a cosmological analysis with the best ground- and/or space-based data available in the second half of the PhD program.

Expected Results: The overarching goal is to answer the question whether the tension in the clustering strength mentioned above is real or not. This PhD work will contribute to pushing the significance of this finding to decisive levels or identifying a so-far unaccounted systematic error. It is expected that the candidate will write at least two first-author papers, one of technical nature in the sub-field of their specialisation and one with a cosmological focus. Furthermore, the candidate will become part of the survey teams that conduct this research and co-author a number of other papers on this (and related) subject.

Methods: The candidate will get access to state-of-the-art wide-field imaging data sets and their accompanying calibration data. Methods like image processing for data reduction, machine learning for calibration, and Monte-Carlo Markov Chain sampling for inference will be applied.

Candidate Requirements: An MSc degree in astronomy/astrophysics or in physics with a specialisation in astronomy/astrophysics and a basic education in cosmology is required. Good English language skills are essential. Prior in-depth knowledge of a programming language like Python is strongly desired. Soft skills and good communication is required to work successfully in the teams that this project is embedded in.

Motivation for CSC application (max 250 words): The candidate will become part of one of the world-leading observational cosmology groups measuring weak gravitational lensing. A broad scientific skill set will be taught that covers all aspects of analysing modern wide-field imaging surveys. With the project being carried out within international survey teams, the candidate will naturally build up a large international network and learn to flourish in such collaborations. The PhD project in our group will be characterised by a strong emphasis on communication, through the teaching of good scientific writing by all group members and collaborators as well as training to give professional presentations in various situations. Detailed instructions and tutoring on how

to write successful observing proposals and third-party funding applications will be provided. Moreover, the project will be embedded in the Research School RUB, which offers additional soft-skill seminars, tutoring, and career development.