VUB SCIENCES & BIOENGINEERING SCIENCES

The Research Group
Astronomy and Astrophysics
has the honor to invite you to the public defense of the PhD thesis of

Pragati Mitra

to obtain the degree of Doctor of Sciences

Title of the PhD thesis:

High-precision reconstruction of air shower properties with dense radio arrays

Promotor:
Prof. dr. Stijn Buitink

The defense will take place on

Tuesday, April 20, 2021 at 13h00

The defense can be followed through a live stream. Contact Pragati.Mitra@vub.be for more information

Members of the jury

Prof. dr. Krijn De Vries (VUB, chair)
Prof. dr. Sophie De Buyl (VUB, secretary)
Prof. dr. Dominique Maes (VUB)
Prof. dr. Simona Toscano (ULB)
Prof. dr. Jaime Alvarez-Muñiz (Universidad de Santiago de Compostella, Spain)

Curriculum

Pragati Mitra (1990) obtained her master’s degree in physics from Indian Institute of Technology Hyderabad in 2014. She started her PhD research at VUB in 2016 under the supervision of Prof. Dr. Stijn Buitink. She has presented her research in several international conferences. She has one journal publication as first author and three peer-reviewed conference proceedings and many more collaborative scientific publications as a member of the LOFAR Cosmic Ray Key Science project. Amongst her contributions is the development of simulation tools that arena used by various research groups around the world.

Abstract of the PhD research

Cosmic rays have been an intriguing field of research since their discovery more than 100 years ago. They are the most energetic particles in the Universe. Likely sources include exploding stars and active black holes, but many questions still exist about the acceleration processes and the physics of their sources. When high-energy cosmic rays impinge upon the atmosphere, they create extensive air showers, which are cascades of secondary particles that are observed with various methods. Measuring the radio emission of air showers is a relatively new but increasingly popular method to extract information about the mass composition of cosmic rays. Thus, reconstructing air shower properties with highest precision forms an integral aspect of study for the present and upcoming dense radio antenna arrays like LOFAR and SKA, driving the motivation behind the work presented in this thesis.

The first part of the thesis describes a novel tool that has been developed in order to include realistic atmospheres in the simulations at the time of observed air showers. It is now used for the analysis at several air shower detection experiments around the world, not only limited to radio arrays. The effects of the realistic atmospheres on the widely used cosmic ray mass estimator shower maximum, X_{max}, are demonstrated using LOFAR data and a general correction formula is provided to compensate for the non-inclusion of exact atmospheric effects.

In the second part of the thesis the shape of the longitudinal profile of air showers is studied. It carries information about the mass of the primary cosmic ray but is also sensitive to the hadronic model used in the simulation. In combination with existing reconstructions of the altitude of the shower maximum it provides a unique potential to constrain hadronic physics in a regime that cannot be probed by the LHC. It is demonstrated that highly dense arrays like LOFAR and SKA are sensitive towards these subtle parameters.

To make such an analysis possible there is a need for simulations that are as fast as full Monte Carlo codes like Corsika but orders of magnitude faster. A detailed study of a semi-analytic framework - MGMR3D is performed. Various modifications within the code lead to very accurate reconstruction of $X_{max.}$ Furthermore, it is demonstrated for the first time that the shape of the longitudinal