



New Physics from the Sky

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Organisers

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Abstract. The LHC and direct detection experiments have had the most interesting possible outcome: the observation of a Higgs boson in isolation. This has left a void in theoretical particle physics, making the traditional questions on the origin of the weak scale and on the nature of dark matter deeper and more confusing than ever. The field has responded by producing a number of ideas that trace the answer to these questions to the early history of the Universe. At the same time, a number of new probes of the evolution of the Universe are planned or are already recording data. This calls for a meeting place where particle physicists, astrophysicists and cosmologists can join forces to refine theoretical ideas, find new experimental targets and benefit from the expertise needed to answer the most pressing questions in fundamental physics. This workshop offered the particle physics community access to a wealth of present and future cosmological data. It also gave, to the astrophysics and cosmology communities, an overview of the latest ideas that connect their disciplines to the fundamental laws of particle interactions.

Keywords. Beyond the standard model, astrophysical tests of fundamental physics, cosmological tests of fundamental physics, dark matter, fine-tuning problems, (primordial) gravitational waves.

Topics

The scientific theme was broadly defined by the title ‘New Physics from the Sky’. It dealt with the progress that existing and upcoming astrophysical and cosmological data can induce on questions of fundamental physics, like the origin of dark matter, of the hierarchy between the electroweak and Planck scales, or of the apparent absence of CP violation in strong interactions. The workshop was organised over five weeks, each on a specific topic, plus a sixth week covering all of them:

1. Dark Matter
2. Astrophysics
3. Cosmic coincidences
4. Low- and high-redshift cosmology
5. Gravitational waves
6. Symposium

Context and Motivations

A vigorous experimental program will dramatically extend our understanding of the history of the Universe within the next ten years. The Cosmic Microwave Background (CMB) will be probed with unprecedented accuracy and we will increase our knowledge of the Milky Way a hundredfold. A vast effort is underway to probe the structure of the Universe at redshifts between roughly 2 and 20, and the blooming field of gravitational wave astronomy will offer us yet another window on the early Universe. This is a series of momentous events that will not only have an unprecedented impact on astrophysics and cosmology but also on particle physics.

These events also represent a shift from the past few decades, in which most of the progress in particle physics was made with colliders. Indeed, while the Large Hadron Collider (LHC) has established the Standard Model at a spectacular precision, it has not delivered clear signals for the needed physics beyond the standard model. Many physicists have started to turn their gaze to the Sky in search for answers to the open questions in fundamental physics.

Furthermore, the most appealing explanations for the origin of the weak scale and the nature of dark matter are under attack by experiment, leaving some of the most urgent questions in the field more open than ever. This has stimulated a number of new paradigms for dark matter, as well as for tying the weak scale to the early cosmological evolution of our universe. Many of these new theories can be tested in cosmology and astrophysics in the immediate future.

It was extremely timely to bring the theoretical particle physics, cosmology and astrophysics communities together at the GGI around these topics, offering plenty of excellent opportunities for cross-fertilisation between all these fields.

Attendance and Scientific Activities

This workshop was the third organised at GGI in 2021, and the second to also take place in person (in addition to online, for a mixed format), after the covid-19 measures were relaxed. It was attended by 87 participants in person, and by many more online. Each week was attended by at least 23 participants in person.

Two distinguished scientists attended the workshop supported by the Simons Foundation: Asimina Arvanitaki (four weeks) and Geraldine Servant (two weeks). Junior participants (PhD and postdocs) in person accounted for just over 50% of the total and participated very actively in the various sessions. Overall, the event was lively, the discussions were engaging and very participated, and the feedback received was extremely positive.

Those who participated in person were selected from a pool of around 150 applicants. The selection process had to be constantly monitored and updated because of the many, mostly covid-related, cancellations and shortened stays.

These included two would-be Simons fellows, which meant that we were able to use Simons support for only two participants. The fact that, despite these many covid-induced troubles, we managed to fill the maximum capacity of the GGI for almost every week is a possible indication of the resonance of the workshop in the community. As far as online participation is concerned, we received about 200 applications, which were all accepted.

The schedule was kept purposely light for every weeks, including the symposium, so that participants had plenty of discussion time. Each week started with a ‘Gong-show’ on Monday morning, during which all those participating in person had up to a minute to introduce themselves and the themes of their recent interest. This allowed them to start getting to know each other and break the ice, and for some participants it served as a scientific discussion starter.

The five workshop weeks hosted one or two seminars a day, which, together with the discussions that followed, lasted up to two hours in total. Speaker names were proposed by the organisers among the in-person participants. Each week, the organisers encouraged the participants to propose discussions around a topic, to be attended (if possible) by all participants. The resulting activities were proposed and led by Stefan Vogl (week one), Asimina Arvanitaki, Savas Dimopoulos and Giovanni Villadoro (week three), Giovanni Villadoro (week five), Paolo Creminelli and Tomer Volansky (week six), and most of them were very well received, stimulating further informal discussions. The workshop, in coordination with the GGI Tea Breaks, also hosted a special seminar by Savas Dimopoulos, who shared his personal view of what we have learned from half a century of Beyond-the-Standard Model theory and searches.

The final Symposium hosted between two and four seminars a day, followed by a structured discussion. Each day of the Symposium roughly covered the topic of one of the preceding weeks. Most speakers and discussion leaders of the final Symposium were invited several months in advance and, due to the uncertain covid-situation back then, we were able to draw up a plan with roughly half of the speakers attending in person and half online.

All the seminars and the following discussions were streamed. The recordings are available on the GGI YouTube channel.

Selected results

The new results presented at the workshop and the engaging discussions triggered by many of them confirmed the workshop’s motivation and timeliness on the frontiers astrophysics, cosmology and particle physics. In terms of astrophysics, the results went from new detection techniques for light dark matter candidates, with stellar basins for example (see Figure 1), to novel X-ray probes of axion physics. In terms of cosmology, they touched both phenomenological aspects, such as

the new lessons primordial gravitational waves could teach us about fundamental physics, and model-building ones, such as new connections between phase transitions and dark matter. On a more theoretical level, the workshop hosted and offered a platform to most leading figures of the novel approaches to the hierarchy problem, which tie the weak scale to the evolution of the early universe. It is perhaps not an exaggeration to say that the resulting discussions, beyond being extremely instructive, played a role in shaping the future of this research direction.

Final considerations

We are on the brink of a new data-driven era in cosmology. This was the best time to bring different communities together and pave the way for the next discovery in fundamental physics. Based on our personal impressions as organisers, on the excitement and enthusiasm surrounding the numerous scientific discussions, and on the positive feedback received from the participants, we think that this was a very successful workshop. We guaranteed active participants with profiles consistent with the specific topic of each week, ranging from particle physicist model-builders to experts in astrophysics and cosmology. Last but not least, to our knowledge this was the first post-covid workshop to be held in person, worldwide, centred on physics beyond the Standard Model, an aspect which also contributed to its success. We hope that this event contributed to consolidating the GGI's excellent reputation for long topical workshops.

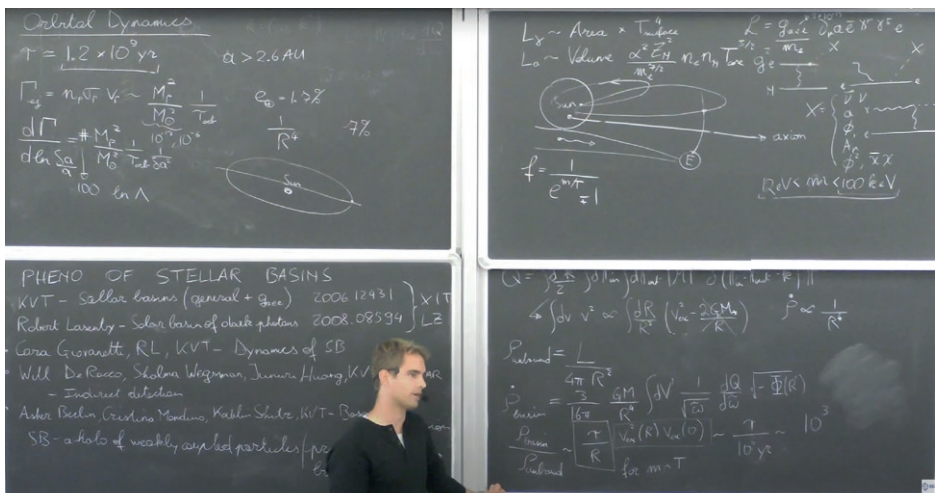


Figure 1. Talk by Ken Van Tilburg on “Phenomenology of stellar basins” recorded and available on the GGI YouTube channel.