

# The Bewildering Nature of Ultra-diffuse Galaxies

A Lorentz Center workshop, held from 13-17 August in the Oort location.

## Scientific Report

One of the most spectacular discoveries in extragalactic astronomy over the past couple of years has been the detection of a hitherto unknown class of galaxies, which are characterised by very low central surface brightness and large effective radii, comparable to the Milky Way or larger. They are therefore dwarfs in terms of luminosity yet giants in terms of size. Dubbed Ultra-Diffuse Galaxies (UDG), they appear to be more numerous than the galaxy population of higher surface brightness, span a wide range of environments (from clusters to filaments), and to be extremely dark-matter dominated. Some people call them “failed” normal galaxies. Measuring the masses of UDGs remains one of the many challenges in this field. Their detection has only been made possible recently thanks to either dedicated facilities (e.g., the Dragonfly array of telephoto lenses, or targeted observations in large telescopes), using state-of-the-art data reduction pipelines.

For the community, this class of galaxies is very interesting, since it gives them a promising way to actually constrain the processes that govern the formation and evolution of galaxies. UDG science has far-reaching implications: the abundance of UDGs is tightly connected to the nature of dark matter, and their formation mechanism is strongly tied to the processes that regulate star formation. However, the selection techniques used to detect these galaxies are known to be biased, and we may be missing many of these objects. Many of them have been found in clusters, with very few UDGs known in the field, where distances are hard to obtain, but this could be a “streetlight” effect, and new HI-based detections are finding many (blue) UDGs in the field, whose properties seem to differ from the ones in clusters. Samples are still rather small, given that these observations are less than 2 years old.

The aim of the workshop was to put together people of the four communities involved (instrument makers, observers, data analysers and theoreticians), to bring each of them up to speed with progress in the other communities. The workshop explored the directions to head in the next few years, and develop a consensus in the way to analyse the current and future datasets, and remove, for example, foreground cirrus. The definition of requirements for future instrumentation was discussed, and new collaborations were established. Very importantly, discussions were held on the validity of current formation models, and whether new models have to be developed to better fit their properties.

The meeting was very successful. We reached the limit of 55 participants from all over the world (including South America, Australia, South Korea etc.), with representation from all major groups around the world. There were talks on new observational surveys, detection of UDGs, the connection to other types of galaxies, differences between UDGs in clusters and in the field, stellar populations, UDG formation and new instruments for the future. There were presentations, and lots of discussions about results presented in the previous sessions. There were some separate discussion sessions, of which the topics were suggested by the participants. One discussion focused entirely on the UDG NGC 1052-DF2, a galaxy for which one group (van Dokkum *et al.*) has claimed that it is basically devoid of dark matter, while others (Trujillo *et al.*) contest this. The discussion was interesting, although it did not lead to a clear conclusion, but at least it was clear where the disagreement was, and what observations need to be done to solve the disagreement.

There were presentations by established researchers, such as Pieter van Dokkum, Dennis Zaritsky, Jean Brodie, Michelle Collins and Nacho Trujillo, but also excellent presentations by PhD students and postdocs, such as Shani Danieli, Aku Venhola, Nicola Amorisco, Arianna di Cintio and Javier Román. The presence of many young people made the workshop very lively. The fact that this was such a new and limited topic, with most major players present, meant that many discussions were of a very high level. The format of the meeting favoured interaction between the participants, in particular between observers and theorists. Each session ended with a long discussion of at least 30 minutes. And often in the afternoons we had discussion sessions on topics provided by the participants, always leading to constructive discussions.

On Wednesday afternoon we had 2 tutorials, by Mohammad Akhlaghi on faint object detection using *gnaastro*, and by Arianna di Cintio on Theoretical Modelling of UDGs. Both were well attended. On Thursday evening a lecture for the public was given by Roberto Abraham, on *‘Exploring the Ghostly Side of Galaxies with Dragonfly’*, in the Boerhaave Museum.

It is not easy to predict what the outcome of the workshop has been. However, it is expected that more people will start using the large imaging archives (especially those of the Hyper Supreme Camera of Subaru) to look for ultra diffuse galaxies themselves. Only a fraction of the science that can be done with this archive has been realised until now. One will also look at field galaxies more carefully for objects that will fade into UDGs at later times. The comparison between clusters and field, up to now, has not been fair, since people mostly have not taken into account the differences in age of the galaxies. A clear result of the workshop is that globular clusters in UDGs could be very important tracers of their mass. This will lead to more interest in those systems. And finally, there is clearly a lot of interest in a future satellite mission that will image the low surface brightness Universe. Realising this satellite will take time, since it is an expensive project, but meetings like this are needed to recruit support. It is clear that such a satellite will lead to a significant breakthrough in the field, making it possible to see remnants of previous galaxy interactions in a large part of the Local Universe.

### **Organisational report**

Two points were raised by participants: (1) the attendees were split in two groups, staying at different hotels. This hindered many informal discussions that take place both during breakfast, dinner or after-dinner. (2) The public for the “public talk” at the Boerhaave was mostly comprised by the participants to the workshop, and there were very few people from the general public. Also, we asked some serious amateur astronomers to participate to some sessions, to no avail.

**Overall**, we very much liked the format of the Lorentz Workshop, with its informal settings and lots of time for discussions in small groups between the talks. The conference dinner, on a boat, was great, with good weather, excellent food, and more good discussions. The support by Tara Seeger, who also prepared a webpage with the contributed talks for the participants of the workshop, and the other staff was excellent. We think that the participants have enjoyed the Lorentz meeting and will be happy to return to Leiden when the opportunity for a next Lorentz workshop arises.