DOI: 10.18727/0722-6691/5253

Report on the ESO/Center for Astrophysics | Harvard & Smithsonian Workshop

Galaxy Cluster Formation II (GCF2021)

held online, 14–18 June 2021

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Galaxy clusters are both important cosmological probes and the large-scale environments influencing galaxy evolution. Processes such as ram pressure stripping, active galactic nucleus feedback and mergers, both on smaller galaxy-galaxy scales and larger cluster-cluster or cluster-subcluster scales play a major role in temporarily boosting and eventually throttling star formation in massive galaxies. The early assembly of galaxy clusters in particular remains a crucial phase for investigation. But it is a difficult one to probe, owing to their redshifts and the messy astrophysical processes involved in so-called "protoclusters", defined as as-yet unvirialised massive assemblies of galaxies, gas, and large dark matter overdensities that will one day form into bona fide galaxy clusters. This second workshop in the Galaxy Cluster Formation series, GCF2021, followed many advances in the field of study covering merging clusters, high-*z* protoclusters, and cluster assembly since the first workshop, held in 2017, GCF2017.

Galaxy clusters are the most massive objects to have formed by the present epoch and are likely the most massive that will ever form, given the accelerating expansion of the Universe. In the hierarchical picture of structure formation, the formation and assembly of these massive objects began 1–3 billion years after the Big Bang, and thus the past 10 gigayears have seen the rise and fall of galaxy cluster assembly. A protocluster found in the simulations of Bassini et al. (2020) and presented by Alex Saro at the workshop is shown in Figure 1.

An introduction to the motivations for the Galaxy Cluster Formation (GCF) workshop series is provided in Mroczkowski et al. (2017). Much has happened in the four years since the first workshop, GCF2017[1], was held, though the best work towards fully understanding these systems lies ahead, using upcoming and planned new facilities such as the Square Kilometre Array (SKA), the Atacama Large Aperture Submillimeter Telescope (AtLAST), ESO's Extremely Large Telescope (ELT), the Nancy Grace Roman Space Telescope, the James Webb Space Telescope (JWST), the Advanced Telescope for High-ENergy Astrophysics (Athena), and the Lynx X-ray observatory.

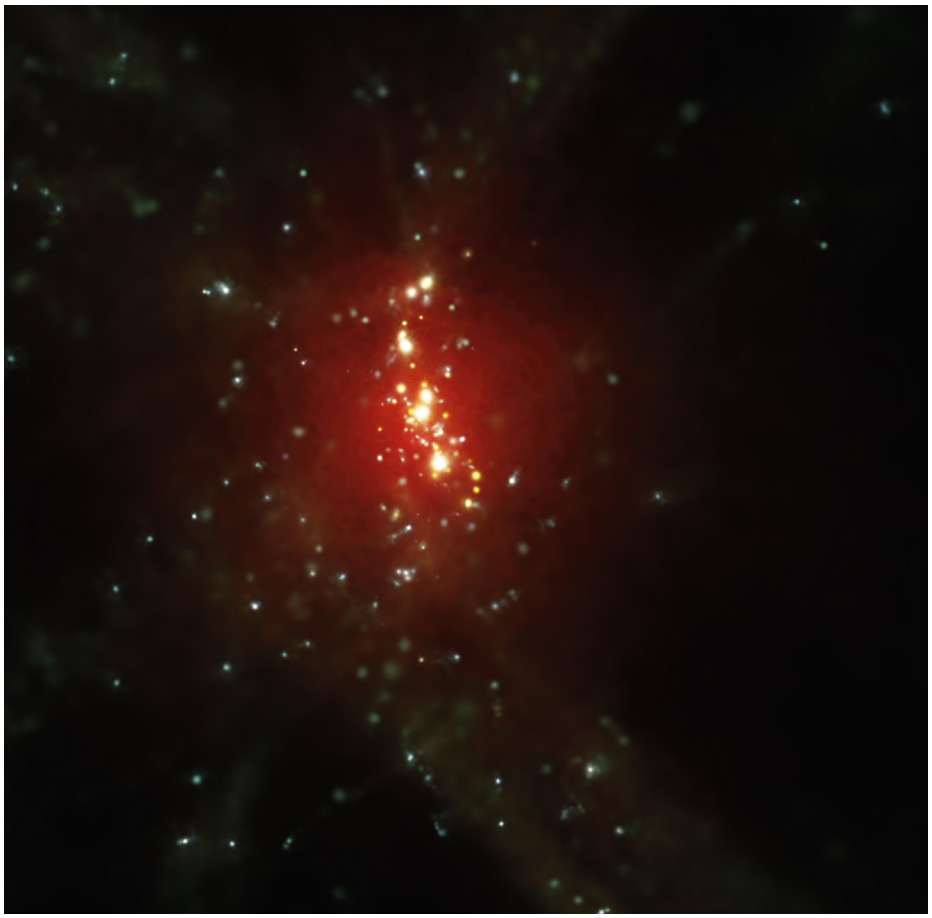

Figure 1. Simulation of a proto-cluster at $z \sim 2.5$ found in DIAGONA (Bassini et al., 2020). The image was produced by Alex Saro using the Splotch code (Dolag et al., 2008).

The second workshop in the GCF series, GCF2021[2], covered a wide range of topics, including simulations, pioneering work on protocluster and cluster searches, studies of the evolution from protoclusters into clusters, processes that both promote and quell star formation, and how to estimate their mass.

A recurring theme in the workshop series is the identification and characterisation of protoclusters, which motivates observations across the electromagnetic spectrum. In particular, it remains a challenge to determine protocluster masses and assembly stages, and to estimate how massive they will grow to be. One of the main conclusions of the workshop is that protoclusters and clusters are not in fact a dichotomy, but rather are situated on a relatively continuous spectrum.

The workshop addressed a wide range of science topics. For instance, the session focusing on lower-redshift galaxy and black hole evolution, as seen from the perspective of the larger cluster/protocluster environment, revealed the need for deeper investigations into preprocessing (for example, interactions of galaxies, filaments and subgroups with other galaxies and the large scale environment) and cluster-wide processes (for example, group accretion and merger-driven shocks), both of which serve as

important but understudied pathways for the transformation of the member galaxies. Jellyfish galaxies were discussed in detail, addressing open questions as to how these disrupted galaxies are shaped by their environments. Not only is galaxy evolution heavily impacted in low-*z* clusters, but results showed that all types of active galactic nucleus activity can be promoted in such overdense environments. The workshop revealed opportunities for knowledge exchange between the lower- and higher-redshift cluster communities, with the possibility of unveiling and studying extended proto-cluster-like structures and mergers at lower redshift still undetected by current instruments. The participants agreed that new instruments such as Athena, the 4-metre Multi-Object Spectroscopic Telescope (4MOST), and Euclid will be transformational in unveiling these hidden populations.

It was originally intended that GCF2021 would be held in person in 2020, but it was delayed because of the COVID-19 pandemic. A considerable effort was made to adapt the workshop to a successful online format, with many suggestions coming from within ESO and the wider community as represented by the workshop scientific organising committee (SOC). The meeting itself was hosted on the popular online meeting platform Zoom, and streamed live on YouTube for those who could not participate directly. Despite the distribution of participants across the globe, the number of active attendees during the live Zoom sessions was very high, fluctuating between 120 and 160 live Zoom participants throughout the five days of the workshop. In order to accommodate more time zones around the world, we recorded all but two of the presentations (subject to permissions) and posted them online on YouTube[3] after editing by an external professional video editing service. The videos garnered significant views from participants during the workshop and reached a broad audience during and after the conference. As of 25 August 2021, the workshop YouTube channel has 115 subscribers, over 3300 views and a total watchtime of almost 280 hours.

Interactions mainly took place in two ways. First, the questions and discussion during the workshop were primarily through the Slack chat platform, which we organised in the following way. Each day was assigned its own Slack channel, while general announcements, personal introductions, job postings, SOC discussions, helpdesk issues, and random conversations each had their own channels. Each session of the workshop had a main chair to moderate the talks, and a Slack chair to monitor for relevant questions during the talk. During the discussion session, the Slack chairs constructed polls related to the main themes they identified for the session. These polls were disseminated using Mentimeter. The result of using Slack and Mentimeter was generally successful, and may have encouraged more active participation by early-career scientists.

The second component to the online interactions was through Gather, an online conference tool that participants

Figure 2. Conference photo montage produced by David Sobral using screenshots from Zoom and Gather.

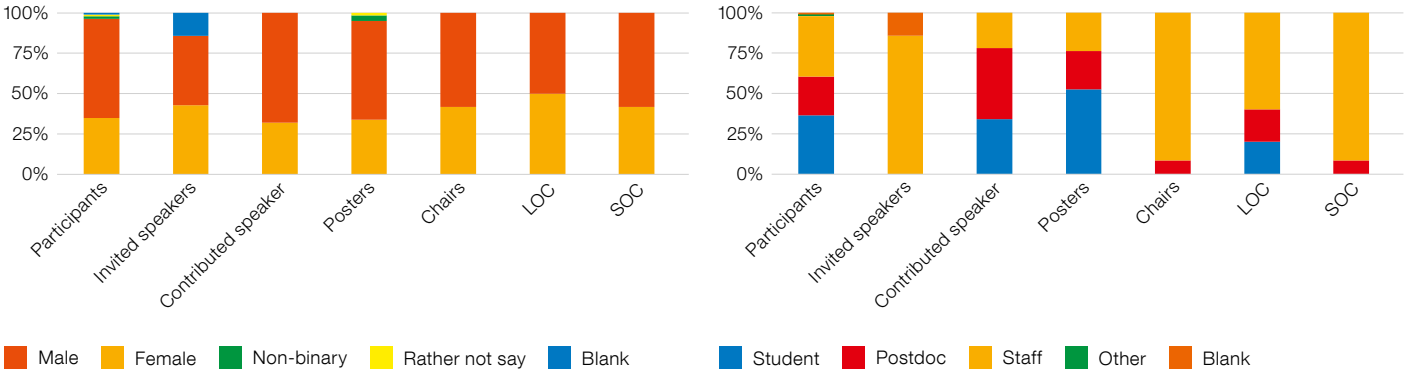

Figure 3. Charts depicting the distributions of gender (left) and career stage (right) of the participants in the workshop, where we note the categories shown may not accurately reflect the complex reality.

use to interact with a virtual space via an avatar cartoon, allowing one to visit poster sessions and meeting rooms, meet colleagues, and generally wander around as if in a real conference venue. Mixed feedback indicates it was generally successful, though a number of users reported delays and that disproportionately heavy CPU resources were required for both the software and web-based interfaces to the platform. A montage snapshot of the participants in Zoom and their avatars in Gather is shown in Figure 2.

Similarly to GCF2017, the majority of the presentations were collected on a voluntary basis, and are now available on the Zenodo platform[4], which provides Digital Object Identifier (DOI) links and is indexed by the SAO/NASA Astrophysics Data System (ADS).

Using Mentimeter, we conducted an exit poll after the workshop to gauge participants' perspectives on it. The consensus from the 45 respondents was that the workshop was extremely well received, with particular praise for the use of recordings that made the workshop more accessible, for the use of Slack to continue discussions after the live sessions and for the interactions in Gather. Whilst the consensus was that the conference was a great success as an online event, the vast majority of respondents hoped that the next GCF workshop will take place in person.

Demographics

As was the case for GCF2017 and many other ESO science workshops, we sought to ensure that the presenters were a fair representation of the community. Whilst we expected fewer than 150 participants, in the end we had 192 registered participants, of whom 67 were female, 118 were male, 3 were non-binary, and 4 did not identify. This was a dramatic increase over the 100 participants at GCF2017, and based on feedback from the participants was likely facilitated by hosting the workshop online and not having a registration fee. We note that only 72 of the participants were senior scientists, whilst the majority were early career scientists (graduate students and postdocs). In order to ensure active participation, we contacted those who did not submit an abstract for a talk or poster to verify that they were legitimately interested astronomers. We note that only 18 registered participants did not connect to the workshop.

Of the seven invited review talks selected by the SOC, three were by female scientists, three were by male scientists, and one speaker did not self-identify. Of the 50 accepted contributed talks, 16 were by female speakers and 34 by male speakers, whilst for the 59 poster presenters, 20 identified as female, 36 as male and two as non-binary, and one did not self-identify. The SOC itself comprised five female and seven male scientists, with one female and one male co-chair. These simple demographics are depicted in Figure 3.

Following a similar methodology to that successfully applied for talk selection in GCF2017, one SOC member removed names and identifying information from the abstract submissions and abstained from voting in the talk selection process. The result was that the allocated talks and posters reflect the gender distribution of those submitted. This also represented fairly the overall distribution of the participants, as the majority of participants had either a talk or poster presentation.

Acknowledgements

We are grateful for support from ESO's Directorate for Science and for contributions from the Center for Astrophysics | Harvard & Smithsonian that enabled the use of the widespread online meeting platform Zoom. We are also indebted to the members of the science and local organising committees who made this workshop a success.

References

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Dolag, K. et al. 2008, New Journal of Physics, 10, 125006
Mroczkowski, T. et al. 2017, The Messenger, 170, 63

Links

[1] GCF2017: https://www.eso.org/sci/meetings/2017/GCF2017.html
[2] GCF2021 workshop programme: https://www.eso.org/sci/meetings/2021/GCF2021.html
[3] Workshop YouTube channel: https://www.youtube.com/channel/UCntCTDx2OHfUbnpm4gUHtWg
[4] Online proceedings: https://zenodo.org/communities/gcf2021