IAU Symposium 352:
Uncovering early galaxy evolution in the ALMA and JWST era

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Castelo de Santiago da Barra
Viana do Castelo, Portugal

Post-Meeting Report

E da Cunha & J Hodge (on behalf of the SOC)

IAUS 352 Participant Group Photo

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Final Scientific Programme

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09:15 - 09:30	da Cunha & Hodge	Welcome and opening remarks
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09:30 - 09:55	Smit	An ALMA view of galaxies in the Epoch of Reionisation (invited talk)
09:55 - 10:20	Finkelstein	Discovery of the Most Distant Star-Forming and Quenched Galaxies in the Universe (invited talk)
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11:30 - 11:45	Bouwens	The Prevalence and Physical Properties of Extremely Low-Luminosity Galaxies in the Early Universe
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09:25 - 09:40	Nanayakkara	A VLT/MUSE analysis of HeIIλ1640 emitters at z=2-4
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12:15 - 12:30	Romano	13C/18O ratio as a litmus test of stellar IMF variations in high-redshift starbursts
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Session 6: Spatially-resolved analyses of z>2 galaxies (Chair: Sobral)		
09:00 - 09:25	Wuyts	Resolved views of early galaxy evolution (invited talk)
09:25 - 09:50	Rujopakarn	Sub-galactic views of cold gas and dust in distant star-forming galaxies: pushing the ~100 pc frontier at z ~ 3 (invited talk)

09:50 - 10:05	Bezanson	Spatially resolving the relics: The inferring the physics driving the quenching of massive galaxies from kinematics at z~1 and beyond
10:05 - 10:20	James	Mapping the Structure and Source of Outflows from Star-forming Galaxies at z=2-3
10:20 - 10:35	Dessauges	Molecular clouds in a Milky Way progenitor observed 8 billion years ago
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11:20 - 11:35	Ritondale	Resolving on 100 pc-scales the UV-continuum in Lyman-emitters between redshift 2 to 3 with gravitational lensing
11:35 - 11:50	Man	Lensed quiescent galaxies at z~2: what quenched their star formation?
11:50 - 12:05	Cochrane	Observed and predicted high redshift galaxies, resolved across the wavelength spectrum
12:05 - 12:20	Tadaki	A sub-kiloparsec-scale view of un-lensed submillimeter galaxies
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14:30 - 14:55	Amorin	Local analogues of high-redshift galaxies (invited talk)
14:55 - 15:10	Jaskot	Neutral Gas and the Escape of Ionizing Radiation: Lessons from the Low-Redshift Green Peas
15:10 - 15:25	Bian	Evolution of Ionized Interstellar Medium from High-redshift to Low-redshift.
15:25 - 15:40	Gonçalves	ALMA observations of local analogs of high-redshift star-forming galaxies
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16:30 - 16:55	Weisz	Lessons from the Local Universe (invited talk)
16:55 - 17:10	Senchyna	Local star-forming dwarf galaxies as windows on reionization-era stellar populations
17:10 - 17:25	Fisher	DYNAMO: An Upclose View of Turbulent, Clumpy Galaxies

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Session 8: Synergies with other facilites & Future outlook (Chair: Walter)		
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09:25 - 09:40	Boogaard	Nature and physical properties of gas-mass selected galaxies using integral field spectroscopy
09:40 - 09:55	Maseda	Ultra-faint Lyman Alpha Emitters with MUSE
09:55 - 10:10	Alves de Oliveira	The role of the JWST near-infrared spectrograph NIRSpec in understanding the assembly and evolution of galaxies
10:10 - 10:25	Rieke	JWST Advanced Deep Extragalactic Survey: NIRCam Imaging to z>10
10:25 - 11:00	Morning coffee	
11:00 - 11:15	Bunker	Spectroscopy with the JWST Advanced Deep Extragalactic Survey (JADES) - the NIRSpec/NIRCAM GTO galaxy evolution project
11:15 - 11:30	Kassin	Toward a New Understanding of Disk Galaxy Formation
11:30 - 11:45	Mutch	Connecting observations of the first galaxies and the Epoch of Reionisation
11:45 - 12:10	Casey	The Brightest Galaxies in the Dark Ages: Galaxies' Dust Continuum Emission out to the Reionization Era (invited talk)
12:10 - 12:35	Session 8 Panel Discussion	
12:35 - 13:00	Session 8 Poster Sparklers	
13:00 - 14:00	Lunch	
14:00 - 14:30	Poster viewing	
14:30 - 15:20	De Lucia & Ellis	Reflections on accomplishments and challenges (invited)
15:20 - 15:30	da Cunha & Hodge	Announcement of poster prizes & Concluding remarks
21:00 - 23:00	Public event at Teatro Sá de Miranda (in Portuguese)	
SATURDAY, JUNE 8		
21:30 - 23:30	Public stargazing event at Praia Norte (in Portuguese)	

Summary of scientific highlights

We had several interesting talks about the current state of the art of detections of the faintest, most distant early galaxies (Smit, Finkelstein, Bouwens, Oesch, Atek). Thanks to HST and Spitzer, often aided by gravitational lensing, we can go deep into the low end of luminosity (and mass) functions of early galaxies, getting close to recovering all the sources responsible for reionization. However in order to really get there, we will need JWST (Oesch, Bouwens, Renzini talks). Efforts are now focusing on not only detecting the faintest, most distant galaxies, but also characterizing their physical properties. ALMA is providing exciting new results in this area, as shown by Smit, Hashimoto, Bowler, Carniani. Mostly [CII] and [OIII] line detections at z>6 with ALMA are providing spectroscopic redshifts for the sources, as well as in some cases dynamical masses and information on the ionized gas. To measure the dust continuum in these sources remains challenging, with some tantalizing observations suggesting that dust grains might be very different than what we observe in the local Universe. A current open question is what is the dust temperature and luminosity in these sources. Answering this will require multi-band ALMA measurement.

In the theory session we had many interesting updates on the state of theoretical early galaxy formation models (Dayal, Arata, Ceverino, Ma, Hutter, Naidu). These models are making predictions on the properties of galaxies in the epoch of reionization that will be directly in the future tested by JWST observations of those galaxies, and also by Square Kilometre Array observations of the 21cm neutral hydrogen signal at reionization. We also highlight the talk by Narayanan, who presented a new model for interstellar dust formation, growth, and destruction that takes into account all known physical processes affecting the evolution of dust grains, and is included in a large-scale cosmological simulation, allowing us to follow the total dust content of galaxies in a way that can be compared with future ALMA and JWST observations.

Spectral energy distribution (SED) models of galaxies are needed to translate our multi-wavelength observations into physical parameters that can be compared to theoretical simulations and models. Currently SED model developers are getting ready to interpret the future vast amount of data on high-redshift sources that will be enabled by the JWST (e.g., talks by Leja, Gomes). A critical step is to produce realistic spectra, including both stellar continuum and nebular emission, especially in the rest-frame UV and optical (talks by Charlot, Hirschmann). In order to do that new stellar evolution ingredients that are still uncertain are needed (for example, stellar binaries and rotation; Nanayakkara, Schaerer, Stanway), as well as robust photoionization models. We had an interesting discussion session about the challenges in producing SED models for the future, when many of their ingredients (stellar evolution, stellar spectra, initial mass function) are very uncertain at the early evolutionary stages when the metallicity was low.

We had several talks about the detection of quasars at high-redshift (Bañados, Venemans, Fan), which trace high density environments at high redshift (z>6) where galaxies and massive central black holes are rapidly growing. These are ideal environments to test the galaxy-AGN connection (e.g., Alberts, Bischetti, Juneau, Humehata talks). ALMA is enabling great strides in this kind of science by observing the interstellar medium of these objects, both in dust continuum, [CII], and CO (e.g., Venemans, Izumi, Sharon talks).

In the session dedicated to the interstellar medium, we had updates on the ALMA large programmes ASPECS (Aravena), and ALPINE (Le Fevre), as well as additional contributed talks

reporting on ALMA studies of the molecular gas content of high-redshift star-forming galaxies with ALMA (Williams, Suess, Magdis, Liu). These studies are unlocking a key component in our understanding of how star formation is fuelled at cosmic dawn and beyond.
Another avenue worth highlighting are detailed studies of strongly lensed, bright dusty star-forming galaxies, which allow us to dissect the interstellar medium down to molecular cloud scales and study small-scale physics effects (such as turbulence) on star formation (Spilker, Falgarone, and the talks by Rujopakarn, Dessauges, and Tadaki in the following session). Another highlight is the use of CO isotopes in the ISM, which can be observed with ALMA at high-redshift, to trace variations of the stellar initial mass function (Romano talk).

Another approach that holds a lot of promise for future combined studies with ALMA and JWST is to obtain resolved, multi-wavelength observations of star-forming galaxies so we can trace both their stellar component (past and current star formation), and their interstellar medium (fuel for future star formation), at similar scales. ALMA and ground-/space-based large telescopes (VLT, Keck and HST now, ELT and JWST in the future) are ideally matched for this purpose (talks by Shivaei, Wuyts, Bezanson, James, Lang, Ritondale, Cochrane). A common result from current studies seems to be that there is often a mismatch between the extent and/or location of the rest-frame UV/optical emission produced by stars, and the infrared emission produced by dust. This can tell us something about the morphology and structure of early galaxies, and how the stellar component is growing , but highlights that caution must be taken when correcting the stellar emission for dust attenuation. Some ambiguities remain due to the fact that high spatial resolutions cannot be achieved in the rest-frame near-infrared with current facilities, which would be closer to a pure stellar distribution (i.e., unaffected by dust); JWST will help resolve this issue.

We had a very interesting session on what can be learnt from local analogues to high-z galaxies; this demonstrated that there is indeed a lot of potential for the two communities of local and distant Universe studies to collaborate. A promising approach is to select low-mass, low-metallicity, high star formation galaxies locally that presumably resemble the first galaxies that contributed to reionization, and study them in the exquisite detail enabled by their relative closeness (e.g., talks by Amorin, Gonçalves, Senchyna, Fisher). Such studies focus, for example, how calibrating observational diagnostics for star formation and metallicity, or measuring quantities like the escape fraction of ionizing photons. The main challenges are still how to define exactly what constitutes a low-redshift analogue, and whether true analogues of young galaxies can be found in our evolved Universe.

In our last session, we had several talks about new observations with the MUSE integral field spectrograph on the ELT (Bacon, Maseda, Boogaard), which give us a preview of the potential of combining this type of observations with ALMA. We highlight the discovery enabled by MUSE of ultra-faint Lyman-alpha emitters at high-redshift, which are very young primeval galaxies with very low metallicities and high star-formation rates, and presumably would contribute significantly to reionization (Maseda); these will be prime targets for JWST in the future. We also had exciting previews of the capabilities of the JWST instruments for high-redshift galaxy evolution science, and descriptions of the planned GTO programmes (Alves de Oliveira, Rieke, Bunker).

Executive summary

The main goal of this IAU Symposium was to bring together the international community of observational and theoretical astronomers in the field of early galaxy evolution, with a special focus on new results from the Atacama Large Millimetre Array (ALMA) and preparation for new research and synergies with the soon-to-be-launched James Webb Space Telescope (JWST). We consider the symposium to have been a major success. The main science highlights are summarized earlier in this report. Here we focus on other key areas of the organization of the symposium, including our very successful collateral events.

Diversity and equity

Through every step of organizing this symposium having a diversity and equity in terms of gender, geographical location, and career stage, were a major concern. Below we list some statistics which are helpful to assess diversity and equity, as well as our initiatives to improve on them, and challenges faced.

Statistics

Invited speakers: we aimed to invite as close to 50% female speakers as possible. Our final fraction of female invited speakers is unfortunately below that, at 35% (this number is actually closer to the fraction of female astronomers in the field).
We identify a few reasons for this. First, two of our female invited speakers had to cancel their participation at very short notice, leaving us not enough time to find suitable replacements. Second, female invited speakers were much more likely to refuse our invitation due to prior commitments. And third, this was compounded by our effort to achieve geographical balance: in some areas such as Asia and South America we could not find suitable female speakers in the field to invite. We note that a significant fraction of our invited speakers (35%) are postdocs and young faculty (hired as faculty in the last year).

Session chairs: the session chairs (who also lead the scientific discussions at the end of each session) were drawn from the members of the Scientific Organizing Committee for the most part. Our SOC had 16 members out of which 8 are female; however, the majority of female members of our SOC (5 members) had to cancel their attendance, which left us with a limited pool of female session chairs. Two of the three female SOC members were the SOC chairs (Hodge and da Cunha, also LOC chair), who had other organizational duties and responsibilities during the symposium, and therefore could not chair a session. We included one of our invited speakers (Casey) as session chair in an attempt to improve the gender balance, however we did not manage to achieve our desired 50/50 gender split.

Contributed speakers: this was a highly over-subscribed symposium, with 231 submissions for contributed talks and only 54 contributed talk slots available in the programme. The abstract submissions were grouped by session and selected by the SOC via a grading system. In some cases the grades were adjusted to maximize the gender, geographical, and career stage diversity of the contributed speakers. 42% of contributed speakers were female (compared to 35% abstracts submitted by women), and 49% were early-career researchers (ECRs), i.e., students and post-docs (compared to 55% submissions by ECRs).

Everyone who had submitted a contributed talk abstract but was not allocated a slot in the programme was invited to present their abstract as a poster.

Efforts to increase the visibility of poster presenters

Given the significant over-subscription rate for contributed talks, and since a large fraction of poster presenters were early career researchers, we developed the following initiatives to increase the visibility of poster presenters:

1) *Poster sparkler sessions*: at the end of each science session, poster presenters in that topic had the opportunity to present one slide on their poster for 2 minutes.
2) Poster viewing sessions: special time allocated to poster viewing in the programme (30 minutes each day after lunch).
3) Refreshments at coffee break were provided in the poster areas to encourage poster viewing during those breaks.
4) *Best poster* by an early career researcher competition, which was judged by our SOC members and invited speakers.
5) *Poster quiz*: we asked each poster presenter to provide a question on their poster, which we included in a questionnaire for participants. Each question had to be posed so that once must read the poster to answer. The person to answer the largest number of questions correctly won a symbolic prize.

Additional equity and diversity efforts

To encourage family caregivers to attend the symposium (who are still women in the majority of cases), we provided an on-site babysitter service free of charge to the participants. This was a very successful initiative in the sense that the participants who used the service were very positively impacted; however, the interest in this kind of service at conferences is still relatively low, and we only had one child full-time and two children part-time. We still view this as a constructive initiative for the future, and in the case of our symposium the cost was still relatively low enough to make it worth it.
Additional equity and diversity efforts included to ensure that all participants were familiar with the IAU anti-harassment policy, as well as an explicit reminder to participants to maintain a collegial and ethical environment through the symposium at the opening remarks by the SOC chairs, and the availability of SOC members to assist should any problems have arisen.
We also ensured that the conference venue was accessible for those with mobility requirements and that all provided meals (coffee breaks, lunches, and the social dinner) were compliant with participants special dietary requirements.

Dedicated science discussion sessions

A novelty of our programme is that, at the end of each science session, we invited all the speakers of that session to the stage for a panel science discussion moderated by the chair of that session. This allowed for more in-depth discussions between speakers and other participants than the usual quick Q&A after each talk. This format also allowed for more participants to get involved in the discussions, even those who are usually very vocal and participative, because they had more opportunities to contribute.

Collateral events

This IAU symposium was rich in collateral events for the local community of Viana do Castelo, which had a very positive impact in the community's engagement with astronomy in general, and in the visibility of the IAU in particular. This was achieved thanks to the excellent collaboration with the local authorities, in particular the Viana do Castelo City Council and Mayor, and the important activities co-organized between the LOC and the University of Porto. The connection with the local community and sense of contributing to the local scientific culture were no doubt one of the most rewarding parts of organizing this symposium. We strongly encourage future IAU symposium organizers to think about how they can use the opportunity of organizing a symposium to not only produce a stimulating meeting for professional astronomers and astronomy students, but also to enrich and build ties with local communities that do not always have access to astronomy teaching and outreach events. Below we briefly our collateral events.

Fully accredited teacher training: this workshop was co-organized by the University of Porto and the "Ciência Viva", and the topic was *New tools for Astronomy in secondary school*. This workshop was taught by two professors of the University of Porto, Prof Carlos Martins (LOC co-chair) and Prof Paulo Mauricio, for a total of 25 hours between March and June, 2019. This was a unique opportunity for local high-school teachers to obtain fully accredited training in astronomy, free of charge and without having to travel outside of Viana do Castelo. This was further supported by City Council, who provided the venue for the workshop free of charge.

Welcome reception & press conference: these two events were organized with the Viana do Castelo City Council. The welcome reception was a chance for the conference participants to get to know each other and also to interact with the local authorities, including the Mayor. The press conference increased the visibility of the symposium (and of the IAU) in the local press, and was a valuable opportunity to talk about the science topics of the symposium to a broad audience, and to advertise the public events.

Public talks: we organized a free event of public talks (in Portuguese) in the Municipal Theatre. The event was presented by Miguel Gonçalves, a well-known Portuguese science communicator, and we had talks about the IAU (by Prof Teresa Lago), the European Space Agency and the JWST (by symposium participant local Dr Catarina Alves de Oliveira), and early galaxies (by SOC member Dr David Sobral). The talks were followed by a panel Q&A including all the speakers and also Dr Elisabete da Cunha, symposium organizer. This event was a success, very well attended by the locals, and with visibility in the press. The public really engaged at the Q&A session.

Stargazing night: we also organized a free stargazing event at the city beach, in collaboration with the Planetarium of Porto, who provided the telescopes and presenters, and City Council. The attendance exceeded expectations, with about 300 locals of all ages coming to the beach despite the windy evening. The main attractions were the Moon craters and Jupiter. This event was such a success that it motivated City Council to organize more regular stargazing events in Viana do Castelo in the future. To do so, they are planning to invest in a few telescopes and get the local amateur astronomy community involved. We think this has a lot of potential to become a lasting positive impact of the symposium in the local community.