# Panel Discussion @ GalPatagonia - 15.Dec.2017

## Questions on Galaxy Evolution / Physics to be answered in the Next Decade

**Panel Members:**

**Garth Illingworth, Julio Navarro, Alexandra Pope, George Rieke, Marcia Rieke**

**Moderator:**

**Karina Caputi**

# Questions on Galaxy Evolution / Physics to be answered in the Next Decade

## ✦What is in your perspective the most important galaxy evolution/physics question that we should be able to answer within the next decade with forthcoming telescopes?

**Replies**:

**MR**: NIRCam - we should know number of z>10 galaxies.
**GI**: ALMA and optical synergies - clearer insight of SF at early times - timescales and how it proceeds in massive galaxies. Do they grow differently? Unusually massive galaxies? What are they?
We need high spatial resolution studies - ELTs + AO + modelling.
**GR**: first BH - Subaru surveys as pathfinders. Magnetic fields. PAH studies. Better modelling/theory understanding. Submm polarimeters + stellar spectra to help understand these issues.
**AP**: Lilly-Madau plot - what happens at z>3? LMT fundamental.
Role of dust. Gas and dust through ALMA studies
**JN**: How reionization happens - find first galaxies. How local analogues really describe high-z sources. MW studies. Dark energy studies with Euclid.
Question from audience **(L. Pellizza)**: what about finding Pop III? **MR**: maybe a GC which contains PopIII. Some spec with JWST will show features that suggest PopIII. Predicted numbers are low.
**GI/MR**: Objects at high z - what is their nature? we see strangely massive objects. Maybe we are as confused as 20 years ago with first z~3 objects. High-z objects with sub-structure? what is in there?

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## ✦ Is our current work methodology completely ok? Or which techniques need to be adapted for the interpretation of the new data?

**Replies:**

**MR**: combination of images at different resolution is now a problem. JWST: PSF size varies by x5-10. Matching different bands. Optimal data combination - how? Use of priors. Imaging analysis currently based on HST. But JWST has larger lambda range. More difficult to homogenize.
**GI**: computational progress, but techniques quite similar. We need more realistic models.
Data processing: big data - how to deal with that? Euclid and WFIRST - larger problem. Optimal processing - how?
**GR**: advances in simulations impressive over last decades. How to know simulations are right? Models of lensing clusters - still need to provide convergent solutions.
**AP**: interpretation of fine structure lines in ALMA. - it is not clear when/how/why they are present or absent as there are too many variables. It would be nice to have solid testable predictions and better observational statistics.
From audience (**K.Kohno**): beyond z=6, are we selecting galaxies in an unbiased manner?
**AP**: We need to learn more from low z to understand high-z sources.
**MR**: How do we prove that we have seen first objects? You need very high-quality spectra to tell difference.
**JN**: take into account how far we have come. Encourage bold ideas and disagreement. Simulations: unlikely to explain galaxy formation from first principles -- too complex.
**GI**: Data - be careful of discussing first data products. *Stay close to the data*. Derived data products are more difficult to control. Collaborations with industry to analyze big data? LSST will need rapid analysis of large data volumes.
**KC:** Radio community is already taking action with respect to big data analysis - collaborations with industry (e.g. IBM) already underway.

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## ✦ Once we discover the sources of reionization, what's next?

**Replies:**

**AP**: go back to low z!  and understand objects better, go down in luminosity.
**GI**: role of AGN unknown, particularly at reionization. Insight of galaxy buildup after reionization - full of subtleties that we don't know.
**GR**: SMBH and their relation to their hosts - gravitational waves. How do SMBH form?
**JN**: sources of reionization - not just discover them. Need to understand them. Connect observations at different epochs - clarify evolutionary paths. How was the MW at z~3?
**AP**: Origins Space Telescope - a lot of discovery space in the IR. A very large IR telescope to study SF regions within galaxies. Galaxy physics - buildup of metals. Understand ISM in detail.
**GI**: Complexity of galaxy evolution - mid-IR and sub-mm at high resolution. Also optical and near-IR. Different telescopes to tackle the study of galaxy physics, rather than single mission.
**GR**: big costs unsustainable? X-rays and other wavelengths need technological advances. Keep different approaches and do not bet all to single mission.
**MR**:  what are building blocks of galaxies? understand them with high-spectral resolution. JWST not good for measuring masses of tiny bits. How do we probe hierarchical merging? May not be probed with JWST.
**GI**: search for life. Politicians would like some areas to be developed. They press us in directions which are not necessarily in our interests. Think broader.
**GR**: gravitational waves will take many resources. Dark energy. Will WFIRST solve dark energy problem? Keep field lively.
**From ?**: what can we do about political constraints? we can't afford another such expensive mission like JWST. Discovery space partly tailored by politicians/public. Request to discover life. We need to have integrity declaring what we do, but at the same time comply with society/political requests.
From audience **(A.Fontana)**:  we are reaching size limit of what we can do. Maybe we are at the ceiling. Even in Europe, ELT is a very large investment and has downsized with respect to original concept.
**MR**:  how much more complex can we go? JWST technology has been challenging. ***Paradigm shift in how we do things?***

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## ✦ Are there important questions in galaxy evolution that can't be answered in the near future? What new facilities do we need to tackle them?

**Replies:**

**GI**: ***Need of Flagship missions for 2030+***
**MR**: low-mass BH. Evolution BH-bulge relation. Go to first principles.
**JN**: nature of dark matter. May still be an open problem in a decade from now.
**AP**: finding first galaxies which do not have any metals (e.g. just hydrogen clouds). Origins Space Telescope (NASA Infrared telescope concept for 2020 decadal survey) can see warm molecular hydrogen beyond reionization and into the dark ages.
**GR**: AGN physics - needs interferometry in near-IR. Only a limited number will be studied in coming years.
Very high resolution astronomy to understand BH and galaxy physics.
From audience (**P. Troncoso)**: evolution of gas? Not clear how much progress ALMA will make.
Molecular gas surveys over large areas.