The Art of Measuring Galaxy Physical Properties

INAF, Milan, Nov. 18-22, 2019

This doc is designed for keeping track of Question & Answer after talks and during discussions, plus any suggestions you have for upcoming discussions. Everyone is encouraged to help keep track of Q&A. If you have a question about a talk, you can post it in the Q&A section following a talk title during that talk and someone watching this doc will try to ask it.

MONDAY, Nov. 18

rachel somerville - cosmological simulations of galaxy properties

Q: Can you tell us more about the logo of SMAUG?
A: Thank you for asking that - we put a lot of thought into that. It's a dragon (Smaug being the dragon in the Hobbit) and the symbol matches the Cosmic uroboros connecting the largest to the smallest scales.
Q: You emphasized the importance of understanding resolved gas for star formation. How well can you predict from cold gas in simulations where the gas comes from? Can you compare simulation parameters to nearby ALMA data?
A: Simulations are good at telling us where gas comes from; can trace that back with a Lagrangian code - we will publish that for the FIRE-SAM comparison. Can also compare with ALMA data - look at Popping papers; CO emission comes from dense clouds that are not resolved in simulations so must put in a sub-grid recipe.
Q: When you paint mock galaxies onto Illustris, you must have to repeat galaxies given limited number of morphologies.
A: Yes, galaxies are repeated, so should be careful about any large-scale correlations found between galaxy environment and morphology.

Clotilde Lagle - Making the most of optical to IR photometry: SED-Fitting on Large Surveys

Q: You showed that ust assumptions seem to modify SFR results by a factor of 10. What's happening to make the effect that large?
A: The U and UV bands are the most affected by dust, which are also the ones the estimation of SFR relies the most on.
Q: How do assumptions about SFH shape affect SFR or does dust dominate that error budget?
A: SFH shape has some impact but much less dramatic than dust.

Q: Were you able to use COSMOS spectroscopy to look at dust observed in those galaxies?
A: Good point. Now that we know that dust is so important, we can try to refine SFR computation.

Marc Huertas-Company - Confronting the theory of galaxy formation with observations with generative models

Q: What is the primary advantage of using pixel CNN vs. the GANs?
A: The advantage of the regressive models is that you estimate a formal probability distribution.

Rhea-Silvia Remus - How to Decipher a Galaxy's Assembly History: Insight from the Magneticum Simulations

Q: Did I understand correctly that galaxies in which we see a decline in the v/sigma profiles versus radius can only be made by minor mergers?
A: The signal doesn't get destroyed because the merger doesn't go far enough to destroy the object. The few observations I have seen - not yet public - seem to find the same trend.
Q: Mergers as a function of geometry and time since the merger?
A: There's a paper out. Looking at isolated merger histories. If you come in along the plane, you can destroy anything and build up a gigantic disk as observed. If you come in in a different direction, you build up the halo.

Andrew Battisti & Elisabete da Cunha - Current challenges in modelling the SEDs of high-z galaxies

Q: You found that COSMOS SEDs require a 2175A bump with 30% strength of MW, but could it instead be that 30% of galaxies have dust with exactly MW-strength bump?
A: That's a fair point. Our result provides a distribution, and it peaks at 0 - roughly ⅓ of the galaxies don't need a bump at all to explain their SEDs. The key aspect is that you only notice the bump in an SED when there's a lot of dust extinction. UV-selected galaxies (typical at high-redshift) have a bias against high dust values, and they don't need a bump at all. But here we purposely used IR-selected galaxies, which should have significant dust, and we did find that a good fraction of them require a MW-like bump.
Q: For energy balance, isn't this a problem for garden-variety spirals, where the IR might be isotropic but the UV/optical surely isn't? How would you change the codes to get that right?
A: Good question, but I haven't worked on that before.

Alex de la Vega - Dust attenuation assumptions and spatially resolved quenching in CANDELS

Q: Do you do any PSF correction? You should have red rings.

A: There hasn't been any cut applied for the PSF correction. But a colleague found that this creates only at most a 5% correction in colors. Shouldn't affect things beyond 1 kpc.
Q: Notes that recent Starkenburg+ paper found the opposite - that most simulations quench inside-out. Would we be able to disentangle variable-attenuation dust law with IR measurements?
A: Not sure. Typical answer would be yes. Would like to add spectra in near future to solve age-metallicity degeneracy.
Q: Could you comment on physical processes that could explain outside-in quenching? Seems more likely for satellites, but CANDELS sample is dominated by centrals.
A: From a quick reading of merger simulation papers, gas in remnants tends to swell to the center; that could keep the central SFRs high as the outskirts quench. Galaxy harassment is another possible mechanism.

Emma Curtis-Lake - Modelling M*-SFR Relation at High Redshifts: Future Constraints from JWST

Q: You illustrated the problems with assuming any particular SFH shape. I suggest that you use the smooth, non-parametric SFHs that Kartheik Iyer will talk about tomorrow morning.
A: Thank you.
Q: Wasn't sure if you were modelling things with different uncertainties as a function of mass. Have you tried running it with no data, just sampling priors?
A: Model accounts for level of uncertainties. Yes, you can do that (shows plot).
Q: What is the effect of SFH on H alpha/H beta that you're worried about - seems like it shouldn't be a problem using fluxes instead of EWs.
A: I'm assuming that you just measure emission lines and not continuum so cannot correct properly for amount of stellar absorption.

Will Bowman - Physical properties of z~2 emission-line galaxies using MCSED

Q: What's up with the high [O III]/H beta ratios? Could it be AGN?
A: Probably not AGN since we excluded X-ray sources.
Q: What is the motivation for us to change to use your MCSED code?
A: I'm unlikely to offer you a compelling reason. We were motivated by wanting a flexible code that does what we need, and we succeeded.

Viviana Acquaviva - How can machine learning help measure the physical properties of galaxies?

Q: Given that resources are finite, what's the most important work you'd like to see simulators do to provide you with the tools you've described?
A: That could be a great but long conversation. In part, it depends on what's possible. Simulators know best where the simulations are failing.

Q: Given that interpretability is an issue, do you lose your ability to come up with physical properties or observables when you move to an ML approach?
A: That's problem and technique dependent. A lot of these techniques really aren't satisfactory for certain problems, but for some problems the interpretation is straightforward.
Q: Comment that errors/uncertainties with ML is moving quickly and it's possible to estimate proper uncertainties and this should be a priority.
A: Agreed 100%!

Adam Carnall - Physical Parameters from Spectroscopy with BAGPIPES

Q: What hope do you have to use your code to understand the SFH of AGN hosts?
A: Haven't tackled AGN with this code. I'd like to include AGN models in the future, but AGNFitter and Prospector can already be used for that.
Q: Low metallicities in z=1 massive galaxies that you seem to be finding are hard to understand. Could it be a systematic problem with template spectra in the UV?
A: This could be caused by a combination of wavelength evolution, late-time quiescent evolution, and outflows vs. Iron peak elements. Template spectra in the UV could also be a cause of trouble.
Q: In a paper, we showed that metallicities at z=0.4 from Lick indices match those seen in templates, so there must be a problem in the modelling.
A: Thanks - I'd like to check out those references.

Seb Turner - Testing a cosmological galaxy simulation with unsupervised machine learning

Q: Would it be better to do the comparison in the observational plane, where it's easier to simulate the observational errors, since the clustering might be very sensitive to the effect of those errors?
A: Clustering should respond to the shape of the data rather than individual errors, but we are aware that data suffers from errors.
Q: K-means and related algorithms are sensitive to outliers. Are you eliminating outliers somehow before performing the clustering?
A: Our processing of the data appears to be robust to the influence of outliers.

Daniel Masters - Maximizing the Information from Imaging Surveys of the 2020s

Q: Every time I use a SOM, it seems powerful as a representation tool. But there's very little in the literature in terms of guidance on how big to make the map - how do you approach that.
A: Our heuristic is that the map should be big enough that the distance between neighboring cells is roughly the size of typical photometric errors.
Q: Is it possible to use a SOM to do model comparison, such as between dust laww?
A: Not sure. Would have to think about it.

Q: In a paper measuring physical properties, we did exactly that by painting observations making different assumptions onto SOMs.
A: OK.
Q: Many clustering techniques exist. Do they agree on what blind spots exist in the photo-z spectroscopy?
A: Haven't used other techniques as much as SOM, but other techniques seem to agree. SOM is topological but does not have intrinsic advantages otherwise.
Q: You can determine SFR but not SFH from SOM given degeneracies we've seen already.
A: Good point.

Yannick Copin - Forward modeling of galaxy kinematics in slitless spectroscopy

Q: A problem with H alpha is that the emission is extended. How do you disentangle spreading in the grism due to kinematics vs. spatial extension?
A: You're right - you have to mitigate on this aspect, but the kinematic signature is difficult to mimic with a symmetrical spatial distribution of H alpha.
Q: Sample will be bigger than 30 million since we won't only detect H alpha.
A: Sure.
Q: JWST with NIRCAM has R=1500 slitless spectroscopy, which is much better than with HST - did you look into that?
A: I made some simulations for HST-like spectra with Euclid. A good thing with the forthcoming surveys is that the dispersion is much higher, so kinematic signatures will be easier to find.

Sandro Tacchella - Measuring quenching timescales by combining photometry and spectroscopy

Q: You referred to non-parametric SFHs. Important to clarify: data science definition of "non-parametric" is that it converges to the true distribution as amount of data increases.   if you fix the number of bins ahead of time, that is *parametric*, but if you let the number of bins adjust to the data, that is non-parametric. (binned SFHs have unphysical discontinuities but are otherwise ok)
A: Fair enough - number of bins is a parameter I'm playing around with.
Q: Is somebody looking into the kinematics and spatially resolved properties of these galaxies?
A: Susan Kassin is looking into this.

Discussion: New Techniques (moderated by Shoubi Hemmati)

(To vote on discussion prompts, go to www.menti.com, code 584795)
Comment: We've seen enough galaxies, in principle, but we don't have enough data for those galaxies yet.
Comment: That depends on how many properties you want to study - if split sample on each and want multi-wavelength coverage, not enough galaxies yet.

Comment: Not sure. But a good example where we need more data is the CGM, where we just have pencil beams and need new techniques.
Q: What is needed for the CGM?
A: Hard to constrain because low density, low surface brightness. Can improve by going deeper spectroscopy, particularly high-spatial-resolution, high-sensitivity, UV spectra.
Comment: Need spectra deep and high-wavelength-resolution enough to see absorption lines, not just spectroscopic redshifts.
Comment: Mauna Kea Spectroscopic Explorer will have huge multiplex capability, even more than VLT+MOONS, with 1.5 degree FOV.
Comment: VLT+MOONS will get to m=23.5, also MOSAIC project with good Field-Of-View, and JWST will go much deeper on smaller area.
Comment: FOBOS is a proposed Keck spectrograph for 0.3-1.0 microns with multiplex of 1800.
Shoubi: Showing SOM trained on simulated WFIRST colors for galaxies with RIZ > or < 25th magnitude. Euclid will get spectra for the brighter set of those.
Comment: Using empirical galaxy colors and training has the advantage that it is data-driven - you don't get templates that are unphysical and thereby harm the SED-fitting results. Can calibrate the SOMs with very deep observations.
Comment: But I don't think we should trust methods that are trained only on current observations, which lack the depth and spatial resolution that future data will have.
Comment: Maybe there's a compromise - we can use theoretical templates/simulated galaxies to validate methods trained on existing data to make sure they work correctly before applying to deeper future data.
Comment: We don't really understand the small-scale physics in simulations that well.
Comment: Is the purpose of running a simulation to reproduce observations or to understand galaxy formation? Should be the latter.
Comment: We saw good agreement among simulations for galaxy LFs but it disagrees with observations - maybe that means that the observations are wrong!
Shoubi: One of the talks this morning showed Horizon-AGN and uses stellar masses from the simulation. I don't think we have trouble getting ensemble properties such as distribution of stellar masses correct.
Comment: Studies of stars are much more mature than studies of galaxies, but we still don't know enough. The same applies to galaxies.

Marziye Jafariyazani - Combining spatially resolved photometric and spectroscopic measurements to constrain evolution of non-local galaxies

Q: Could you please go back to the sSFR profiles for SED-fitting and H alpha? Why do you call that inside-out growth when the sSFR_SED is flat. The sSFR tells you how long the galaxy would have needed to form stars at current rate to generate observed stellar mass. So that's only meaningful looking back in time over long time periods, e.g., sSFR_SED. When sSFR_Ha disagrees, it means that the trend is changing rapidly - but then better to compare SFRs directly, as in your later plots, and in this case that might be evidence for inside-out quenching rather than inside-out historical growth.

A: We do see sSFR_Ha lower in central regions and higher in the outskirts. Perhaps best to discuss this in detail later.
Q: In slide 6, you compared SFRs from SED-fitting and H alpha. Did you try fitting photometry plus the H alpha line?
A: We haven't done simultaneous fitting. For the photometry, we used the Kennicutt relations to add H alpha contributions to SED fitting to model the SFR. But we didn't use the spectroscopy.

Bianca-Iulia Ciocan - CLASH-VLT: Enhancement of (O/H) in z~0.35 RXJ 2248-4431 cluster galaxies

Q: Are there ALMA or far-infrared observations of this cluster?
A: Not as far as I know.

Luca Constantin - A few StePS forward in unveiling the complexity of galaxy evolution: light-weighted stellar ages of intermediate-redshift galaxies with WEAVE

Q: What is the sensitivity you can get - how much star formation does a burst need to have for you to detect it?
A: Haven't looked into that, but this is really a question about the timing of the recent burst more than the mass fraction involved.

TUESDAY, Nov. 19

Christina Williams - A Brief (~2 billion year) History of Massive Quiescent Galaxies

Q: Wondering about some of the SED fits you showed. Is the factor of 10 dependence of stellar mass on dust law because the galaxy is so dusty that rest-frame optical light is being heavily extinguished?
A:Really our assumptions about the dust can heavily impact what we find for stellar mass, in this case of high dust amounts.
Q: Regarding very flat attenuation curves, one way to get that is Arp220-like, another is having a heavily extinguished region next to a not heavily extinguished region. Were you able to rule out those explanations?
A: No. Once you have to do this deblending, it becomes quite challenging. People should be aiming to do that in the next couple years, though.
Q: Do we have an estimate of how much stellar mass is missed by current surveys due to these ALMA-dark galaxies?
A: Yes - it's substantial - might be missing 90% of massive galaxies above a certain limit.
Q: What kind of morphology are you putting in the mock images?

A: They're all Sersic profiles, which allows us to follow Arjen's work on galaxy evolution in CANDELS images.

Kartheik Iyer - Galaxy Evolution Probed Through Observationally Reconstructed Star Formation Histories

Q: I was wondering if when you see multiple peaks in the SFH, that could come from two galaxies that merge together with different SFHs - could you probe the merger fraction?
A: Yes! That's a direction we're thinking about. Want to compare with SAMs to see if we could convert these statistics into a merger fraction.
Q: Gaussian Processes don't know that SFR>0. How do you deal with that?
A: Ah. So the way we handle this is to have the GP work in cumulative mass space i.e. integral of SFR vs. time. Take a running derivative to get the SFR. We did make it monotonic by construction, and we avoid extreme cases where SFR would decrease via careful choice of priors.

Chiara Mancini - Rejuvenated galaxies with very old bulges at the origin of the bending of the Main Sequence

Q: If everything is as you described, these objects would be small and compact. What can you tell us about surface brightness and morphology?
A: Yes, the morphologies and sizes are consistent with compact galaxies.
Q: Missing mass due to flattening of dust attenuation curves starts happening at 10^10 solar masses, right where you're seeing bending. What dust attenuation curves are you assuming?
A: Used two different dust attenuation curves - Calzetti & Charlot-Fall for bulges, Calzetti & SMC for disks, but attenuations are small, A_V~0.6.

Lucia Pozzetti - Reconstruction of galaxy physical properties and Star Formation Histories of high-z star forming galaxies from VANDELS (based on Annalisa Citro's Ph.D. work)

Kiyoaki Omori - Identification and Investigation of Interacting Galaxies Using Spatially Resolved Data

Q: You should be able to store the mass that was involved in the SF episode for each pixel and then correlate this with the timescales.
A: Thank you.
Q: Were you able to find any trends with gas fraction?
A: We haven't looked at that yet.
Q: What is the comparison between this dynamical approach and other quantitative estimates of mergers like concentration, Gini coefficient?

A: This is preliminary so we haven't done that yet.
Q: For the post-merger galaxy you showed looks very edge-on. What assumptions are you making in Firefly - is it a two-component model?
A: Dust is fitted at the beginning without any attenuation curve by the actual spectrum.
Q: Did you also consider fast-rotating galaxies in your sample selection?
A: Now starting to consider fast- vs. slow-rotating galaxies. Initially just looked at colors.

Vivienne Wild - The star formation histories of rapidly quenched galaxies at z~1

Q: Are there AGN in your sample?
A: We probably don't have radio-loud broad-line AGN; they would be excluded by the photometric selection

Stefano Zibetti - From points to galaxies: learning from IFS surveys of nearby galaxies

Q: Thanks for pointing out interplay between global and local scales in galaxy formation. One might expect metallicity to depend upon total depth of potential well where the stars formed. Are you therefore surprised that you see such a tight correlation with the stellar mass density?
A: Still have a dependence on velocity dispersion, so that effect does seem to exist, but yes, it's weaker than I would have expected. If you're further out in the potential well, winds appear to be more effective.
Q: Smaller scatter being smaller than your errors doesn't always indicate low intrinsic scatter. Could be due to overestimated errors.
A: Error is 0.15 dex in age and metallicity. These are quite conservative. Systematics start to dominate but we're treating everything with the same models so radial trends are not subject to systematics. Must be seeing the intrinsic scatter, after forcing common normalization.

Ivana Damjanov - (Active) evolution of passive galaxies from z~0.6

Q: In the model that you described where the growth of quiescent galaxies is well-described by minor mergers, you mentioned that progenitor bias might also be important. Could you explain that further?
A: Looking at the size-mass relation for SDSS and then SHELS sub-samples, we can evolve those using our model that accounts for mass growth, size growth, and velocity dispersions. If you look at difference vs. our model's evolution you can see effect of progenitor bias. That effect is much lower than growth from the overall model.

Discussion: Star Formation Histories and Quenching (moderated by Eric Gawiser)

In what circumstances can we infer SFHs, what science should we use them for?

- SFHs come with uncertainties, which may be large for few bands/noisy photometry - safe as long as bias < uncertainty?
    - still worried we haven't fully broken degeneracies between age-dust-metallicity, let alone abundance slopes and variable IMF
    - Q: do we need more diverse stellar spectra? high metallicity-giants, etc.
    - A: yes, always a dearth of good spectra with which to calibrate SPS models
    - Work from smaller to bigger samples, with increasing fidelity. Test methods by measuring quantities on noisy data where “truth” is available from high-quality data.

    - Stop reporting ‘age’, and report robust quantities - t50 or t10?
    - Agree, but t50 is also hard to measure. Light-weighted age is probably much easier to constrain, but probably less valuable in terms of science.
    - Better to report median quantities. Unsolvable degeneracy between start of SF and age.
- SFHs provide an untapped constraint on galaxy formation models and sub-grid simulation recipes, which have already predicted SFHs
    - Kartheik’s working along those lines, sims predict not only SFHs, but also correlations between SFHs and all sorts of other things, environment, morphology, structure, BH mass etc.
    - Problem is that most of the advanced ways are calibrated against sims in the first place, need not be a problem but is something to be aware of. Forward modeling sims is also a consideration. How to do a comparison based on observed space?
    - Variability and burstiness of SFHs can also provide model-independent constraints

- can SFHs reveal the number and duration of starbursts, evidence for compaction, frequency of rejuvenation?
    - Mixing multiple progenitor galaxies into one observed SFH.
    - Corollary: can we use abundances/abundance ratios to disentangle things that merged in/ formed in-situ - inspired by what people are doing with Gaia.
    - This might be possible in the spatially resolved case? Its approaching the fidelity of the SFHs. assuming galaxies don’t merge, reconstruct mass functions and quantify the difference. - this has been done with tau-models by Stijn Wuyts, and something similar using the CSFRD in papers by Adam Carnall and Joel Leja earlier this year.
    - Could take the span of best-fit SFH families at z~4-5 and compare to observations in the early universe
    - Re using the abundance ratios, yes, these provide independent constraints on the SFH and can be spatially resolved.

What have we learned about quenching in galaxies, and what further studies are needed?

- what is quenching? Sandro's definition: 'transition to a state of negligible stellar mass growth due to star formation' - measured via sSFR vs 1/t_Hubble

    - Many hours of discussion in the IQ collaboratory led to an alternative definition - Hahn+18 - decomposition in the SFR-M* plane using Gaussian Mixture Model to identify sources below the Star-forming sequence as green valley and quiescent.
    - Quenching, quiescent, passive and retired galaxies

- inside-out vs outside-in: do observations agree? Do sims make consistent predictions? Do observations agree with theory? How much should the radial profile vary by galaxy?

    - Why should it be one or the other, and not both?
    - Regularity in the CALIFA profiles indicate that it is a mix between the two. In the sims, this depends a lot on the recipes put in for AGN and stellar winds, so there's a lot of model to model variation.
    - Before doing this, need to determine appropriate priors to get this right.
    - A big issue with current observations is dust. UV continuum slopes, stacking, balmer decrements all have their own systematics. ALMA observations might be a way out.

- is there solid evidence that AGN drive quenching in real galaxies?

    - For radio galaxies there's fairly solid evidence that there are outflows that drove out the molecular gas. For other lower-luminosity AGN the quasar mode is less obvious, depends on selection criterion - mid-IR selected AGN show different properties
    - Just because you see outflows doesn't mean it will significantly impact the galaxy. Recent sims show that even low luminosity AGN drive outflows without necessarily quenching the galaxy - how halo-dynamics impacts the galaxy baryon cycle needs to be better studied.
    - Turbulence in molecular gas

- evidence for quenching mechanisms is mostly correlation. Can we find causality?

    - One way is to look into the SFHs and seek evidence of quenching there.

Can we use Star Formation Histories to learn about quenching?

- SFHs (with uncertainties) can reveal quenching timescales?
- Can a combination of radial profiles and quenching timescales rule out (or confirm) our current models of quenching mechanisms?

Carl Ferkinhoff - The Long Wavelength School of Measuring Galaxy Physical Properties

Q: Can you give us an update on the timeline for SPICA?

A: There's still another round of approvals, but I'm not directly involved in the project. Lots of us want SPICA to validate technology for ORIGINS and to calibrate the physical processes. ALMA's only likely to get to 1000 detections, whereas ORIGINS promises of order a million high-z detections. SPICA would be intermediate. Should find out status of SPICA in 2021.

Darko Donevski - Knocking on giant's door: The evolution of dust-to-stellar mass properties in distant, dusty galaxies

Q: You said starburst galaxies are more gas-rich at high redshifts but inferred shorter depletion times - what's the logic?
A: Expected short depletion times may not be valid anymore.
Q: Loretta Dunn wrote a paper in 2011 and found a change in dust-to-stellar-mass ratio for massive galaxies with redshift. Did you differentiate that?
A: Not yet. For simulations like SIMBA, they can match dust-mass functions out to z=1 but have trouble at higher redshifts.

Vasily Kokorev - In Search of Molecular Hydrogen: Constraining the Gas Content of Star Forming Galaxies

Q: You showed a plot of how dust mass depends on radiation field. Does SFR depend on that?
A: That's a really interesting idea. Just from memory, I don't think there's a dependence. But that would be interesting to check.

Wouter Dobbels - Dust & Stellar Property Estimates via Machine Learning Techniques

GitHub repository - paper - summary - interactive plots - slides

Q: Have you checked how the size of your training set affects your results?
A: Yes. For this case, with shallow neural networks, 2000-3000 galaxies seems to be enough.
Q: Still need a physical model to train your sample at some point. It's understandable that when you lack data something like this would be appealing. Do you understand what's driving the improvement versus Bayesian analysis? Where's the magic?
A: The ML approach can use properties that aren't part of SED-fitting and is non-linear. There isn't any magic. If ground truth comes from SED-fitting, we can only hope to match SED-fitting. But here if we don't have Herschel but know the dust properties, then we can make predictions for galaxies that lack Herschel photometry and do better than SED-fitting for those galaxies.
Q: ML is not intrinsically unbiased; it depends on the loss function that you use for training.
A: Your algorithm has to converge, but here it is approximately unbiased.

Quirino D'Amato - On the dust and gas content of high-redshift galaxies hosting obscured AGN in the CDF-S

Q: Since you asked for suggestions, a student of mine, Peter Liang, published a paper last year successfully reproducing the Scoville relation in cosmological simulations at redshifts of 2-4. You can make the scatter much tighter if you have some measure of the dust-to-gas ratio or metallicity.
A: Thank you.
Q: In terms of far-IR properties, temperatures you're finding (65-80 K) are not very consistent with what you expect. You might be probing closer to the AGN than a typical far-IR measurement.
A: I know that far-IR SEDs from these sources are poorly constrained. We constrain dust temperature poorly with one band; maybe we're tracing just the region that is more central.

Anna Gallazzi - Metal abundances of galaxy stellar populations: estimates and implications for galaxy evolution

Q: On the slide with the Bayesian analysis flowchart, how would this diagram differ for a frequentist approach?
A: You would just pick out the best fit model from the likelihood, no prior or marginalization.
Q: To be fair to the frequentist method, it would also allow you to rule out places in parameter space that are a poor fit to the data via e.g., the chi-squared. That's how confidence intervals on parameters get set in the frequentist approach, but I agree that it pays attention to the best-fit rather than marginalized parameter values.
A: Sure. And the risk here might be to give too much weight to models that are preferred by the prior. This is a risk in case of very uncertain observational data, in which the prior would tend to dominate.
Adam - I explained this poorly, but my point was going to be that a lot of nominaly frequentist codes take e.g. the likelihood-weighted median parameter value after fitting across a grid, instead of the maximum likelihood. To my mind this isn't frequentist, it's just doing Bayesian statistics badly by refusing to multiply your likelihood distribution by a prior.
Q: Even in the local universe, the stellar abundances of star forming galaxies can be quite different. How well do you think we know the abundances in the local universe and do you think that could account for the differences with the gas phase being found?
A: We're treating star-forming and quiescent galaxies in the same way, and it turns out that the Bayesian analysis shows a steep relationship between alpha enhancement and stellar mass for quiescent galaxies and a flat relation for star-forming galaxies (but not solar-scaled abundance ratios). Much more work needs to be done, including comparison with independent estimates. Back in 2005, we saw a strong systematic difference between stellar- and gas-phase metallicities in star-forming galaxies, but now that's been revealed to have been caused by calibration issues. So we should take a look at that as well for alpha abundances. It would be

interesting to check how the abundance ratios derived from absorption lines compare with the difference between gas-phase O abundance and stellar metallicity.

Sarah Leslie - Disk inclination is a painful bias but a useful tool: Constraining dust properties at z<0.8

Q: A lot of recent H alpha studies (e.g., Kashino+2013) have found that nebular and stellar reddening are equal for galaxies at these redshifts, but here you find a changing f factor.
A: Plan to include information from additional wavelengths and see how that changes things.
Q: Is the SFMS calculated using UV and NIR? Isn't that plagued by the same issue?
A: We do indeed assume that UV+IR is correct but have investigated different assumptions.
Q: Could you track UV-to-IR ratio as a function of inclination and then use that as an additional constraint in SED-fitting?
A: That makes sense (shows related figure).

Ivana Barisic - A novel approach to measure dust attenuation at z~1

Q: Have your plotted your A4500 against the slope for each galaxy. Is there a lot of scatter?
A: Yes, but there is a large intrinsic scatter and not a lot of correlation.

Zach Pace - Resolved and Integrated Stellar Masses in the SDSS-IV/MaNGA Survey from PCA Fits

Q: I'm surprised about this offset between stellar mass and dynamical mass. The stellar remnants should take into account the 40% but that fraction does not account for gas lost from stars.
A: We do include the 40% fraction, but not the gas lost - let's talk more.
Q: You said that D4000-Hdelta space is well-covered by models. Is that also true in your PCA space?
A: Yes, more or less.

Nima Chartab Soltani - The Role of the Environment in Star Formation Activity

Q: There are claims that at high redshift, the SFR at fixed mass is higher in dense environments (as opposed to the local universe where SFR at fixed mass is lower in dense environments). I was trying to check your plots to see if you see that reversal, but it's not clear.
A: At higher redshift, some studies see the reversal, but in our data we see the familiar relationship from the local universe.
Q: If you color by distance from the S-F sequence, do they look different?
A:Haven't done that yet but will!

WEDNESDAY, Nov. 20

Ylva Gotberg - Advances in our understanding of massive stars and how that affects spectra of stellar populations

Q: Does how fast they rotate relate to their environment and chance of producing a GRB?
A: Good question. Not clear what makes the stars rotate - could be from formation channel, or maybe they've already had a merger. Long-duration GRBs are considered related to fast-rotating stars.
Q: Simulations of mergers of massive stars have shown that 100km/s rotation prevents formation of a neutron star. Do you think this sets a limit on your rotation velocity?
A: That sounds questionable; it's not really clear whether a SN will create a NS or BH and that doesn't necessarily depend on the core properties. So I don't think the lack of NS would be a strong constraint on the initial rotation rate.
Q: I'm struck by 70% of massive stars being in interacting binaries. Is that at *some point* in their main sequence lives, or at any given moment?
A: It's at some point in their overall lives. Most massive stars interact when they become large (giants) so usually after the main sequence. But the more massive they become, the companions become closer, and main sequence mergers (magnetic stars) become feasible.

Margherita Talia - The VANDELS view on the inter-stellar medium of star-forming galaxies at z>2.5

Q: Is there any way to distinguish ISM vs. CGM contributions to these lines?
A: These are slit spectra so we're just looking at the galaxy, but yes it's possible that there is mild contamination from CGM along with line-of-sight.
Q: You said you had a trend with dust content, A_V. Are any of these lines affected by dust more than others?
A: We see the same relation with Si II and C II and C IV ; the correlation is shallower for Aluminum.
Q: I'd like to understand the EW vs. SFR results a bit more. Were they *all* based on stacked spectra? And are your results consistent with Faisst+16 given their large errorbars?
A: Faisst+16 is consistent with flat but not with rising EW vs. SFR, so we have a 2-3 sigma level disagreement. Yes, these are all stacked spectra; if we stack in finer bins of SFR, the uncertainties increase, but we get consistent results.

Nor Pirzkal - Resolved Star Formation in Galaxies Using Slitless Spectroscopy

Q: After you work your magic on the grism data, what is the effective spatial resolution?

A: Basically the resolution of WFC3, .129”/pixel. Can also do this with JWST, will get 2X better resolution with NIRCAM.

Fergus Cullen - Stellar metallicities of star-forming galaxies at z~3.5 with VANDELS spectroscopy

Q: Do you have a sense for how much of the difference inthe mass-metallicity relationship is due to evolution vs. shifting from UV to optical?
A: That’s difficult to know. In the local universe, the two effects are redshift evolution and whether metallicities are derived in the same way. We do plan to look into this.
Q: What SPS models are you using? Do you have a fine enough gridding in metallicity?
A: Starburst99. We interpolate within the metallicity grid in log Z. We have several metallicity values available.
Q: The Sommariva+12 stellar metallicity derivation was finding UV-based metallicity consistent with local, which is significantly higher than what you find.
A: They used indices to estimate metallicity; we use SED fitting, and the discrepancy isn’t very significant given their large uncertainties.

Marcella Longhetti - Metallicity gradients in quiescent galaxies at z~2

Q: Have you done any tests to see if with the expected aging of these galaxies to z=0 you’d be able to still detect the age gradient at z=0?
A: Work is still in progress, we need to check the absolute numbers we obtained before comparing them with other works at different redshift. While the result of an existing metallicity (and age) gradient is reliable, the absolute numbers of age and metallicity need still to be checked
Q: Where are the galaxies you showed lying in the size-mass relation compared to local? Very compact?
A: This one is not a very compact galaxy given the size-mass relation.
Q: If you look at the age profiles in CALIFA, see age gradients of 1-2 Gyr. So it should be possible to see age gradients of the type you’re seeing at z=0 if there isn’t rejuvenation!
A: You’re right because it’s more clearly visible at lower redshift.
Q: In MaNGA we don’t see age gradients at all, shouldn’t be visible due to age-metallicity degeneracy. Evolving passively your age gradients to z=0 should be very difficult to see.

Katie Grasha - Challenges in Stellar Models of Photoionized H II Regions

Q: Could you show the spectrum again? Usually we pretend we know, once you correct with the Balmer decrement, and assuming an IMF, that we know the number of O stars. Does this mean that all of our SFRs are unknown by 30-40%?
A: Afraid so. Can’t prove that yet, but that’s how it appears.
Q: This work reminds me of what we’ve done showing that lower-mass stars are affected by atmospheres. The advantage there is that we have a well-defined MW abundance pattern for

disk and bulge. In your regime, calibrators are in the local universe; that might still work, but how general do you think it will be, or do you need to invest in theoretical extrapolations to model z~7?
A: We have submitted VLT proposals to study low-metallicity stars. We're trying to fill in gaps there so that we don't have to extrapolate so much. That's our next step.

Shuang Zhou - Bayesian modelling and analyzing galaxy spectra with BIGS

Q: Regarding comparison between models using evidence ratio, does this take number of free parameteers for each model into consideration?
A: Yes! Bayesian evidence is integrated probability of observing the data in a given model; you don't need an additional penalty for having more free parameters.
Q: Number of parameters should indeed be accounted for by integrating to get the evidence, but since your additional parameters are about old stellar populations, which will be poorly constrained, have you tested the effects of changing priors for those older population parameters?
A: Good point. We are testing the effects of choice of priors on those parameters.

Nuria Salvador Rusinol - Tiny fractions of young stellar populations in massive ETGs

Q: The UV upturn is the solution to your discrepancy in NUV indices, rather than young stellar populations. UV upturn from all the stellar population gives a better fit and will also agree with the alpha enhancement in these galaxies, even if I agree that the young population is a bit degenerate.
A: I've looked at that paper and will address. When you look at the UV upturn you normally see that it's below 2000A.
Q: That depends on the temperature; it starts below 3000A. It's described by multiple parameters.
A: Our main analysis using post-AGB stars fits the indices, and we find larger fractions than expected from theory. Both effects could be playing a role, so being conservative, our results provide upper limits on the contribution from young stars.
Q: I think you mentioned using exponentially declining SFHs? Could those ever detect a small fraction of young stars? How degenerate would the timescales be?
A: We used multiple fitting approaches (shows figure) so should have a robust result.

Carlos Eduardo Barbosa - A multilevel Bayesian framework to study spatially resolved galaxies

Q: Interestied in how you're implementing your No-U-Turn Sampler (NUTS).
A: It's available as a Python package. It scales better with the number of parameters than the non-Hamiltonian samplers.

Sree Oh - Kinematically disentangling bulges and disks using 3D spectroscopy

Q: Decomposing galaxies kinematically seems really important. Can you classify velocity dispersion to study the kinematics of the system? With a similar analysis you could expand this to higher moments of the velocity dispersion.
A: I'm not estimating higher moments because of S/N limitations, but that's a good point for what could be done on higher-S/N data.

Discussion: Stellar Population Models (moderated by Claudia Maraston & Elizabeth Stanway)

Q: You've thoroughly convinced me that I need to worry about SPS models, but how can we take the ensemble of issues into account analyzing galaxy observations?
A (Elizabeth): You'd only expect the massive populations to have a big effect at young ages, but if you plot Lick indices at 12 Gyr populations, binaries still affect them. I don't know a simple way to implement the uncertainties; these parameters are really present in all analyses, but you're setting a bunch of them artificially to zero as a prior if you ignore binaries.
A (Claudia): There are works where models are taken with extreme assumptions and that affects the age of the universe. When people use unpublished models, it's even more difficult to interpret. As I showed, star cluster ages should be measured from the turnoff only. There is 35 years of literature in which we tried to narrow down the uncertainties. Be careful with those Lick indices, which are affected by alpha-enhanced elements.
A (Elizabeth): Not sure what the input physics in latest unpublished B-C models are.

- It's quite difficult to compare all the models. But for us SED fitters, it would be helpful if you could provide us with some uncertainties on the models.
- A (Claudia): See Bruzual 1996 & Maraston 2005 for those uncertainties - they're long papers but do include that information.
- A (Elizabeth): Agree with Claudia that different physical parameters are important. Uncertainties are often evaluated on just a few runs due to computational challenges.
- [missed the next comment]
- Elizabeth: There has to be a combination of information from different sources. Can look at Globular Clusters and transient rates as well as stellar clusters, but that's a 30-year project.
- One of the observables that's highly affected by uncertainties in SPS models is H alpha and other emission lines; affected by binaries, rotation, abundances. How can we progress in this area?
- Elizabeth: Keep coming back to SN issues. If you look at transient rates over time, if your models aren't producing those correctly, you're not getting massive star evolution right. There's a lot to do with high-resolution, high-S/N, deep spectroscopy. But there are massive degeneracies in the effects of binarity and metallicity and rotation, and

they're connected in the sense that binaries give you rotation. We have a new paper on arXiv this morning talking about this!

- Claudia: Showed a plot extending up to 0.9 microns. Maiolino+ are getting a better fit because this library of stellar spectra is continuous over wider wavelength coverage.
- Was great to see Ylva's plot of He vs. H ionization. That overall discussion makes me wonder if SFR is the parameter we should be thinking about, especially with line diagnostics we're really probing the ionizing photon rate at energies of species we're observing - should we switch to that parameter space?
- Elizabeth: The shape of the ionizing spectrum is really important. That changes with ionizing and stellar atmosphere models. Being pessimistic, we have never seen the ionizing spectrum from massive stars - reconstructed via nebular emission but then have to disentangle all of the abundance effects we heard about from Katie this morning. They are still largely theoretical.
- Totally agree with Elizabeth. Ways of measuring ionizing radiation will help stellar modellers. No models really match the recent galaxy observed by Berg+.
- Elizabeth: There are probably non-stellar components involved.
- Comparing models with each other can be tough - is there a way to make that easier?
- Claudia: The models that we use do have challenging output formats.
- Elizabeth: The IAU tried to organize a working group to get modellers and fitters to unify their formats. Everyone disagreed about what formats to adopt. And the information encoded differs from model to model.

THURSDAY, Nov. 21

Paul Torrey - Bridging the Divide Between Simulations and Observations

Q: It seems that going from observations to parameters involve degeneracies; not clear that this is easier going in the other direction. Is there something that makes it intrinsically easier to go from simulations to observations?
A: No. But we don't have the degeneracies going forwards; the model has a particular value of age and metallicity. But the model might be totally wrong. As you forward-model the observations, you might find that the SEDs you produce don't match observations. The point I'm really making is that we as simulators should more fully forward-model the observations and not requiring observers to meet us in the middle.. If we do fully go into observer-space, it's harder to meaningfully compare an SED than a stellar mass.
Q: Forward-modelling galaxy formation simulations with stellar population models is great; we've done it; but the only uncertainty is the dust attenuation law, but this turned out to be a minimal effect for galaxies without huge SFRs. Also you fix the IMF; that can make a factor of two difference. So I support your suggestions.
A: I agree. For radiative transfer, often the simulation resolution is insufficient for generating clear predictions.

Joel Leja - A New Census of the $0.2<z<3.0$ Universe Part I: The Stellar Mass Function

Q: This is a 14-parameter fit. If you took away or added a parameter, how much does that change your conclusion? Did the final parameter affect the conclusions a lot?
A: That depends on the parameter. The SFH parameters and dust attenuation curve are key for determining stellar masses, for instance, whereas gas phase metallicity is a nuisance parameter that we marginalize over to be responsible.

Xiangcheng Ma - Cosmological simulations with “realistic” feedback: What do we learn and how to test with observations?

Ana Trcka - Reproducing the Universe: EAGLE in SKIRT vs. DustPedia

Q: What is the fraction of AGN in your DustPedia sample?
A: It’s very small - they’re marked differently, with crosses, in the figure, but we didn’t model them differently because so few of them.
Q: One of the challenges is going to small scales, modelling dust obscuration cloud-by-cloud, since the resolution of EAGLE is 0.5 kpc and therefore not good enough. Did you tune model parameters to better match observations?
A: We fine-tuned the parameters before; the procedure is quite complicated to get better resolution. For EAGLE galaxies they are not so sensitive, but with high-resolution simulation this could be more important.

Sidney Lower - Ground-Truthing SED Fitting Methods in Galaxy Observations

Q: What’s the youngest age bin that you’re trying to constrain? You seem to be underestimating SFR - perhaps it’s because you’re trying to constrain a timescale that photometry cannot give you alone; use spectra or let the first bin be broader.
A: 0-30 Myr is the first time bin. Now thinking about using spectra.
Q: It looks like your SFHs use 9 time bins that are fixed ahead of time. That is a huge improvement - it is flexible and getting much more realistic results than simple parametrizations. Nonetheless, it is a piece-wise constant parametrization of the SFH with a fixed number of parameters and is therefore parametric. Non-parametric means having a flexible number of parameters that responds to data quality and, in the limit of infinite data, converges to the true underlying distribution. So you can call this binned and very flexible, but it is parametric.
A: That’s fair - thanks - Prospector does have a flexible time bin option, but I didn’t use it.
Q: The SFH that you’re using is trained on Illustris. When you’re getting stellar masses out, to what extent are MUFASA and Illustris similar, and is it surprising that you can successfully reproduce star formation histories?
A: Not deeply familiar with the SFHs so tough to answer that question.

Q: Want to caution about calibrating measurements with simulations; that forces nature to do what simulations are telling us. Simulations are not the truth.
A: Good point, especially for later discussion.
Q: What prescription do you use for dust attenuation? Can that resolve systematic overestimation?
A: We model dust with something close to Noll 2009. That might involve too much flexibility with UV bump and slope; that produces degeneracies. Prefer Kriek & Conroy, which matches UV bump to slope. Sort of - if we switch, the metallicities hit the prior floor, so there's something we need to fix.

Robert Feldmann - How to deal with incomplete and uncertain data: The star forming sequence of galaxies

Check out github.com/rfeldmann/leopy   (leopy-stat-0.9.1)
Q: Statistical method looks very useful! Can it deal with a detection probability as f(flux) instead of a simple detection limit?
A: At the moment it doesn't do that. You could play with detection threshold as 3 sigma instead of 5 sigma, etc., but it only accounts for uncertainty.

Lamiya Mowla - Breaking the Law? A Revised View of the Relation Between the Sizes and Masses of Galaxies Since z~3

Q: Could you say anything from additional data etc. about the halo size-galaxy size relation at the massive end? I think you're assuming it's linear to perform the comparison that you showed, but is there evidence that it extends
A: Not for the massive end, we don't. From HOC (?) survey, they did find that massive galaxies' light profiles match the dark matter halo mass fairly well at 10^11 M_sun.
Q: In your ALMA data, the velocity scale isn't centered at 0. Is there a velocity offset?
A: For one of these galaxies, there is a roughly 100km/s offset between H alpha and ALMA emission.

Marianna Annunziatella - Fantastic Beasts and Where to Find Them: Monster Galaxies at z>3 and their Characterization

Q: What dust attenuation prescription are you using? A much shallower dust attenuation law could make sense for such high SFRs and might affect the mass measurements.
A: Calzetti law. We checked for varying the attenuation curve and still the galaxies are highly massive.

Discussion: Simulations (moderated by Sara Wellons)

Where should simulators and observers meet and compare results?

- Most popular answer: It depends (not simply physical space or observable space). Important not to overspecify simulation predictions for a particular survey.
- Suggestion that we meet wherever dimensionality is minimal. Also suggested that we meet in multiple places to make sure that agreement is robust.
- Let's think deeply about physical meaning of observables.
- There's a practical value in not over-modelling, since there are many artifacts and observational effects - don't want to be forward-modelling each survey, that's too much work.
- Would the uncertainties you introduce in trying to make predictions in observable space outweigh what you'd get as the benefits of it?
- Plea to everyone to define your terms so that others know how to interpret and reproduce your work.
- Can put different levels of forward-modelling; can stop short of making instrument-specific predictions, allowing observers to add those details later on. What's harder is making panchromatic predictions ahead of time. We can make SEDs and mock images that can be downgraded i.e. convolved with the specifics of a given instrument.

What is the biggest obstacle to making good comparisons?

- Many great answers, including "dust attenuation", "making good mock catalogs", "communication", "resolution", "stress", "physics" and "reproducibility"
- Need to talk to the observers; as a simulator, I could get any relation you want - need to find out what is physically motivated.
- The only way to do this right is for observers and simulators to do the project together.
- Drop the idea that there is one value of the stellar mass. Make sure that everything is reproducible. Make all of the scripts public when you publish.
- Q: But didn't people pledge to work together 10 years ago? Why hasn't it worked yet?
- I think we're doing better. More studies show this cross-collaboration; more simulations are produced to try to explain particular observational results.
- Gentle request that when simulation papers "observe" their simulations, the Abstract still be clear that this is not real data.

There are lots of things still to be figured out in galaxy formation physics. What are the fundamental questions we still have to answer?

- Word cloud produced. Most popular responses were feedback, imf, dust, quenching, dark matter.

- Q: What kind of feedback?
- Stellar and BH feedback both critical.
- CGM is really important!
- Dust is fundamental in sense of needing to solve it first, but cannot afford too many free parameters. Could we move beyond assuming Calzetti to a new consensus law with just one more free parameter?
- Folding small-scale items into sub-grid physics is also fundamental.
- During past 20 years, observations and simulations have both improved incredibly.
- This is a major challenge, but we're making progress.

Arjen van der Wel - LEGA-C: Stellar Populations and Stellar Kinematics of Massive z~1 Galaxies

Q: We analyzed the slope around masses of 10^10 M_sun at an epoch 7 billion years later. So what's the connection? We keep finding rejuvenated galaxies at z=0. Did you pull out an estimate of the alpha enhancement?
A: To make it back to the star-forming sequence at z=0 requires less rejuvenation than at z=1. We have now converged on the data reduction so will start looking at abundances in the spectra.
Q: The idea that the bimodality of the color-magnitude diagram is related to a quenching process, is that related to the idea that rejuvenation would be slower, and then do you find them in the green valley in the same fractions as they would be in the red sequence or blue cloud?
A: I don't think that rejuvenation is generally important for galaxy evolution. Quiescent galaxies attach to the star-forming population. Not necessarily true that galaxies undergo structural changes when they stop forming stars, at least at lower redshifts. At z~1 it's a mix; at high-z, fast quenching may be important for structure.
Q: Is there a connection between velocity profiles and rejuvenation?
A: I didn't show any slides about connection between kinematics and rejuvenation; we haven't found any; rejuvenation events were a long time ago, and we only measure kinematic structure crudely.

Wren Suess - COLOR GRADIENTS are responsible for most of the evolution in the mass-size relation

Q: Could you comment on the dust or age profiles of your galaxies?
A: Not really as I don't totally trust them with only 4-5 resolved points on the SEDs. We're interpreting them as masses primarily, but could look at IFU studies for more information.
Q: A lot of clustering algorithms like to chop a continuum into skinny slices. Do you have an intuition for how that might be propagating into your conclusions?
A: We're not using k-means or a clustering algorithm. We interpret the rest-frame SED to a fixed set of points and then judge how similar the objects are based on a chi^2 test and pull out groups of objects that are similar there. Clearly the SED knows something about that galaxy's mass and size.

Emiliano Merlin - Properties of high-redshift passive galaxies: Number density and contribution to the cosmic star formation history

Q: It seemed like about half of your candidates are low and to the left in the UVJ selection box. A steep dust curve for star-forming galaxies can move you there, instead of being red & dead.
A: Good point. We didn't check that.
Q: Talking about comparison between observations and simulations, you mentioned high-redshift tension vs. TNG100 and SIMBA; the size of those boxes is to expect only a few galaxies of number density like 10^-5 so there's a big poisson uncertainty in their modelled number density.
A: We checked that the volumes are consistent.

Paola Santini - Selection and confirmation of passive galaxy candidates in the early (z>3) Universe

Q: Did you try to fold the information from ALMA into your SED fits?
A: No, I haven't tried. It's something to do.

Nushkia Chamba - The size of galaxies in an era of ultra-deep imaging

Q: How do you measure R_1 from the threshold of 1 solar mass/kpc^2?
A: Using the g and r band surface-brightness profiles, converting to mass profiles.
Q: Wouldn't say R_e is problematic, it's just different - a moment of the light distribution. Central mass density is still important, but you're looking at a different quantity.
A: Sure. The only comment I have in response is that R_e or R_80 or R_90 are arbitrary; we tried to think about a physical motivation before measuring, drawn from Milky Way-like galaxies.
Q: Can't use this definition at high redshift.
A: We have someone trying to do that.
Q: Typically one assumes a Sersic index and tries to measure surface brightness using that. How does this new method compare - is there less scatter?
A: I didn't use Sersic profiles to get the R_e, just integrated the light. In the paper we did vary methods of measuring radii and ours produces the lowest scatter in mass-size relation.

Vince Estrada-Carpenter - Stellar Population Properties of Massive Quiescent Galaxies Derived from Deep Hubble Space Telescope Grism Data

Q: Did you cross-match your sample with the VANDELS sample in GOODS-S? Do you want to work with me to do this for LEGA-C?
A: I haven't. Sure - let's talk!
Q: How do you compute Sigma_1?

A: We took the Sersic profiles and measure the fractional mass out to 1 Mpc.
Q: Did you try fitting just the photometry without the grism spectra?
A: We only ran that for a handful of galaxies. With just the photometry, the redshift is more uncertain. For that small set, the ages didn't look too different, but other properties changed.

Paolo Saracco - Stellar age and metallicity estimates of (ultra)massive galaxies over ~12 billion years

Q: Some of the discrepancies are understood! The difference in age is caused by different stellar evolution tracks; Padova tracks push the ages older. The metallicity is also understood; in our 2011 paper we noticed the difference vs. the published stellar library, partly due to assuming a mixing length into the tracks. Padova tracks are the redder; they have a redder red-giant branch for all metallicities. There is a high debate on which of the two age scales is correct; I want to calibrate on globular clusters; to my knowledge, they haven't yet agreed on one version.
A: Thank you.
Q: Another point to add: neither the set of empirical stellar libraries nor the theoretical libraries (e.g., ionizing spectra) is complete. As many stellar populations people as you have in the room, you'll have that many opinions on what the right single set of models to use would be.
A: Thank you.
Q: Have you also looked at the alpha abundances?
A: We do not have the data needed to check for this. At the edge of the spectral range, the S/N is insufficient.

Discussion: Massive Galaxies (moderated by Amber Straughn)

What's a massive galaxy e.g., at z=1?

- Should it be a relative definition?
- Perhaps simply M_*>10^10.5?

What we think we know about massive galaxies:

- Rare
- Local QGs formed stars early & fast
- Metal-rich
- Predominantly red acros redshift (either QGs or dusty SFGs)

Very massive galaxies at high z: how did they form all those stars so early?

- Most popular answer is unsure between in situ or ex situ processes, or don't have enough data to know which is dominant
- Abundances imply most SF is in situ
- But BCGs have high merger rates so perhaps most mass is formed ex situ

What are the predominant ways that massive galaxies quench?

- Most popular answer: feedback
- Idea: halo acts as a gate-keeper for quenching
- But that's just AGN with a bit of energy preventing the cooling of gas; not clear if this is operating as well in the high-z universe.
- From the dusty galaxy view, the bulk of galaxies that are responsible for increased SFR are free of obvious AGN; will be done forming stars in 100 Myr if no further gas accretes.
- Concerned that sub-grid models in sims are missing ISM feedback and therefore need more energy from AGN than is truly happening in reality.
- Need to understand what quenching is doing to the star-forming gas via a detailed ISM picture. From the point-of-view of knowing if an extra energy source is needed, all models agree that extra energy is needed to shut down accretion; that's where AGN feedback comes in.
- There is an AGN component in local luminous infrared galaxies; may be similar to high-z sub-millimeter galaxies with very high SFRs. Even smaller AGN feedback should not be ignored.
- Q: How about effects of CGM?
- We truly don't understand the CGM. Need to understand the balance between rate of material coming in and flowing out. Resolution is insufficient for both simulations and observations.
- If you better resolve the CGM, galaxy properties seem unchanged, but microscale physics relevant to the CGM needs to be modelled better.

What aspect most strongly affects a massive galaxy's evolution?

- Warm dark matter, if it exists, pushes formation to higher-mass galaxies but doesn't solve the question of having too many massive galaxies at high redshift.

What's your dream scenario for new data to handle these questions?

- Learning about the temperature of the halo in massive galaxies is one way forward.
- See cool species in recombination from ultra-deep high-resolution space-based data.
- Far-IR emission lines are a great mostly-unexplored regime for learning more.
- Physics driving CGM properties will probably be different.

What are the biggest open questions relating to massive galaxy evolution?

- IMF?

FRIDAY, Nov. 22

James Aird - Connecting the physical properties of AGN and galaxies

Q: Are most luminous AGN in quiescent galaxies (i.e. below MS)?
A: Shift towards lower accretion rates (weaker AGN) on average. Luminous AGN in quiescents relatively rare.
Q: Do results change if you include IR selected AGN with X-ray selected ones
A: Interesting question: Might preferentially miss higher SFR hosts. Might bring average inferred accretion rates down.
Q: How does SFR measurement method affect conclusion?
A: Using FIR as SFRI is dangerous. Always balance between AGN/SF emission. Moving to longer wavelengths may be better.

Myrta Symeonidis - The impact of AGN on our understanding of galaxy evolution

Q: What about the same analysis on the stellar mass function?
A: That's the next thing to do.
Q: Just curious: does this AGN fraction analysis agree with Mid-IR PAH features?
A: We use the 11.3 um to calibrate, which is robust to AGN contribution

Yunkun Han - Modelling and interpreting the multi-wavelength spectral energy distributions of galaxies with machine learning and Bayesian inference

Q: Is the Muzzin et al (2013) data an appropriate test given its model-dependent photometric offsets based on BC03?
A: Thank you for pointing this out. After a more careful check of the Muzzin13 paper, I find that the EAZY code has been used to determine the Zero-point Offsets of the photometric data. Since the templates from PEGASE, M05, and BC03 have all been used in the procedure, it is not clear which model dominate the results. Anyway, we still would like to check whether the results of Bayesian model comparison could be changed if the data without model-dependent correction are employed.

Ray Sharma - Evidence of Black Hole Feedback in Simulated Dwarf Galaxies

Q: You're observing simulations, can't you make a stronger statement about the cause of the effects you see?
A: Need to look at outflow properties. Not done yet.
Q: Do you measure stellar masses/rates at end of simulation?
A: Yes, in last 250 Myr at z=0
Q: Do your BH seed masses impact this?
A: Yes, the seed masses are too big because of simulation resolution. They're accreting too much.
Q: Effect of SN-driven feedback?
A: Central densities wouldn't be affected since they're dominated by BH.

Ena Choi - Simulations and mock observations of Active Galactic Nuclei and their hosts

Q: So you have an idea of the gas fraction? Does this explain the difference between your findings and others?
A: It depends on how you define the mergers. We've not checked how it would be different if we matched the merger fraction classification with the previous work. Stay tuned.
Q: Gini-M20 are rubbish at finding post-mergers. Shape Asymmetry is better. You might want to try to that.
A: No classification method is perfect. But our method fails the same way on both simulation and obs so it's a fair comparison.
Q: Have you made mock observations at different timesteps post-merger to look for signatures.
A: Yes.

Poster Presentations

Thibaud Moutard (Local vs Global Quenching)
Q: Is your timescale for quenching or for SF before quenching?
A: Timescale required to get from the MS to the quiescent region.

Andrea Enia (Stellar Mass vs SFR on kpc scales in Face-on Spirals in Dustpedia)
Q: How do you differentiate by SF regions and regions of ISM irradiated by other external stars?
A: This is a pixel-by-pixel fitting analysis. The inter-arm region is problematic. These are right on the sensitivity limit.

Giacomo Girelli (Stellar-to-Halo Mass relation over 12 Gyr)
Q: No questions

Michaela Hirschmann - Black holes, AGN and their spectral observables in state-of-the-art cosmological simulations

Q: How often are AGN missed using BPT diagrams selections?
A: Some of the composites extend well into the SF branch, so they would be assumed to be star forming and their significant AGN component would be missed.
Q: Do you or can you include shock excitation?
A: I'm working on that. Illustris TNG has a shock finder. I'm using new libraries of shock models and am very excited about how shocks may change the picture.
Q: Do you include geometric effects, e.g. extinction by dusty torus?
A: At the moment, not yet. Photoionization models with cloudy are 1D but this needs to be worked on to account for viewing angle and geometrical effects. We intend to do this.

Ivan Delvecchio - Low Accretion Signatures of AGN Emission (LASAGNE): recipes from the radio

Q: You converted 3 GHz luminosity of 1.4 with fixed spectral index? Can the AGN be identified by spectral index?
A: There are shallower 1.4 GHz images in this field, most sources are detected. -0.7 used if no 1.4 GHz is available. We calibrate Radio-IR q on our own data but in general, yes.

Qingling Ni - Does black-hole growth depend fundamentally on host-galaxy compactness?

Q: No questions

Matthew Bayliss - Strong Lensing Assisted Observations of X-Ray Emission From Young Stellar Populations at Cosmic Noon

Q: No questions (everyone is tired and/or hungry and it's lunchtime).

Poster Presentations

Angelos Nersesian (Dust heating with 3D Radiative transfer modelling)
Q: No questions

Alina Boecker (The Art of Measuring Integrated Spectra)
Q: No questions

Ivano Baronchelli (identification of single lines through machine learning)
Q: No Questions

Bryan Terrazas - The relationship between black hole mass and galaxy properties: clues to the physics behind quiescence

Q: The quiescent population has finished growing but in SF galaxies it's ongoing. Does this explain the differences?
A: Models don't constrain galaxy growth well, but agree that there may be ways to think about this which involve star formation histories
Q: TNG thermal to kinetic feedback has a threshold at the black hole mass you observe where quiescents and SF galaxies transition. Is this transition matched by design or fundamental?
A: Some tests have been done but the instantaneous values don't provide a lot of information.

Ian McCheyne - Using deep LOFAR data measure the far infrared radio correlation and the effect of AGN on star formation

Q: What is the angular resolution of the LOFAR data?
A: ~6 arcseconds
Q: Are there any radio detected / IR undetected sources to include?
A: We re-ran the photometry and SED modelling to make sure we have LIR for all radio sources.

Questions for discussion:

1) Observational signatures of AGN feedback

As Andreea Petric has mentioned a couple of times, radio feedback by AGN is established observationally. This is used in simulations to bring down the predicted stellar mass function at the high mass end - originally radio mode was used where radio jets stop intracluster gas from cooling onto the central cluster galaxies

- What about quasar mode? Quenching SF in AGN host galaxies

Is the bimodality in galaxy colours (and/or SFRs) as a function of stellar mass the only thing we have to suggest that this is happening?

Moutard poster… galaxies in the fast quenching path do they have AGN? Relative timescales in fast and slow quenching paths...

- Where and how should we be looking to determine this observationally

2) What are the unique and secure stellar signatures in spectra for galaxies that have powerful AGN
    - PAHs need a lot more work on those, JWST will help
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3) M-sigma relation
    How do galaxies and BHs get onto this relation

4) Simulations - Observations

Does the feedback between the two need improvement