Major concerns:

1. The paper is phrased as focusing on predictions for high-z galaxies but there is little appeal to high-z observations to inform the choice of parameter range to explore and as a consequence significant parts of the paper are of little interest for the galaxy population that it is setting out to explain.[Revise so that the paper is focused on low-*z* galaxies instead…perhaps “How much SF and how much AGN?” – Chris]

2. Parameter ranges. The parameter ranges explored are very much larger than any explored in the literature, and a significant part of the discussion focuses on the behaviour of the models far away from the parameters normally used for star forming galaxies. This concerns densities and the incident ionising flux and it seems the ranges of both have been chosen based on a misunderstanding of the literature. I go into details below. This needs to be fixed and the end-result should be a much reduced parameter space and I am concerned that the difference from other papers in the literature will be less clear.[Revise so that density is cut off at 10^6 and flux at the grain sublimation point. - Helen]

3. Equivalent widths given as reference. The equivalent widths of galaxies at wavelengths >~ 2000AA are sensitive to the star formation history of galaxies on time-scales >100 Myr or so, as well as the different attenuation of the continuum and emission lines

(e.g. Charlot & Fall 2000; Calzetti 1997), and the EWs of MIR/FIR lines are sensitive to the underlying dust emission model adopted. None of this is discussed in the paper and the results are therefore not as interesting/useful as they could be and the discussion and conclusion would almost certainly be modified if the grids had been discussed in terms of incident flux at Earth rather than EWs for instance. This needs substantial work and rewording of the discussion section.

4. Inappropriate modeling in the FIR. The modelling setup is acceptable for most UV and optical lines as far as I can see, but the treatment of some lines such as [S II], [O I], [C II] is not satisfactory. Cloudy has for all lines been run with either a column

density or temperature cut-off. Neither of these are well-chosen for the PDR regions where these ions emit - the typical temperatures here are ~100-1000K and column densities <~10^21 cm^2 (e.g. Hollenbach & Tielens 1997) - conditions your models would not reach (the temperature cut-off will happen before this). You could improve the [S II] and [O I] predictions by going to lower temperatures/lower ionisation fractions, but the treatment of [C II] requires more thought - or removal from the paper (probably the best option). For instance, it is normally agreed that C II originates in the warm ISM

with temperatures of ~100-200K (see e.g. Israel & Maloney 2011; Stacey et al 1991) and your stopping criteria preclude you from properly tracing this line.[Remove these lines from the plots (Helen) and analysis (Chris)]

b) Argue that current binary models (e.g. Stanway et al 2014, 2016, BPASS2), prolong the WR phase at all metallicities so that adopting something like the Padova SED is an acceptable approximation. This is viable but would require a comparison of the Padova SED with BPASS2 SEDs to justify this assumption.

6. Comparison and predictions for JWST.

This section I am afraid is not useful at the moment. It ignores crucial details needed for predictions such as the IGM absorption to the galaxies and the detection limits are not properly discussed or at least not in a way that is useful to the reader. What star formation

rates, what magnitudes, what integration times, what observing plans are the authors considering, none are explained and it also seems there is a major confusion between the NIRCam and NIRSpec instruments.

I should however say that I think the inclusion of this discussion in the text \_is\_ a good idea. It just needs to be done more rigorously and perhaps be branched off as a separate section (or for that sake a different paper). Reference to the JWST ETC

(<http://jwstetc.stsci.edu/etc>/) is also advised. [I think this should be left in the paper, but I’m clueless about how to handle the observing info - Chris]

Detailed comments (Chris handles everything below this point)

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Parameter ranges:

Density: This is discsused in section 3.1.4 and it is argued based on observations of compact and ultra-compact HII region that these have densities exceeding 10^6 cm^(-3).

I am rather confused by these limits and their relevance. I do not dispute their values but they are as far as I know derived for the molecular gas density in these compact regions (this is certainly true for the Beuther et al paper) This is not directly related to the density of the actually ionised HII region that you are interested in for the simulation and such high densitities are indeed very far from any densities actually measured at high redshift (e.g. Lehnert et al 2009) which are almost always below 1000 cm^(-3).

Indeed pressure equilibrium makes this reasonably likely as well - molecular gas has T < 100K and an HII region typically ~10^4 K, so you would expect the density to be ~a factor 100-1000 lower, so going from 10^4-10^6 to 10-10^4 or so.

Thus having a density grid going to 10^10 is completely unnecessary for the application to high-z galaxies. A grid that extends to 10^4 would be more than enough. For a proper PDR simulation a higher density could be appropriate - but then Cloudy might not be the

optimal choice.

Incident ionising flux:

This is poorly explained in the text where limits from Stasinska & Leitherer (1996) and Levesque et al (2010) are discussed. It is said that (p 16): "the upper limit is set by assuming the theoretical maximum QH".

It is not clear what theoretical maximum QH is referred to, but from the numbers it seems it must be the one from Stasinska & Leitherer. However this seems to have been misunderstood: the value of QH depends on the amount of stars being formed - this is often normalised to 1 Msun/yr when given explicitly. The problem is that the Stasinska & Leitherer models are for different normalisations - 10^3 to 10^9 solar masses - now when normalising the incident ionising flux that is of course ok, but there is also a size to consider - 10^9 Solar masses within 10^16 cm gives an average density within the

region 8 orders of magnitude above your grid limit, that makes no physical sense at all. This needs serious re-assessment and will move the grid down towards what previous studies have used.

Page 2:

You write:

~~'Galaxy mergers commonly trigger the enhanced star formation rate (SFR) of starburst galaxies along the far left wing of the BPT diagram' - where do you get this from? I am not aware of a clear study saying this - it is true that Galaxy Zoo classifications show a slight increase in the galaxies with 'merger' classification in this part of the BPT diagram but that does not in any way mean that they truly are mergers, nor that they SF is truly driven by merger activity (e.g. Robaina et al 2009 for a slightly higher z perspective).~~ [ADDED CITATION AND REWORDED]

~~You write: 'in such galaxies' - What does 'such' refer to here - starburst galaxies or those on the far left wing?~~ [CLARIFIED]

Page 3:

~~'could likely be the result of starlight, non-thermal sources, or a combination of the two' - This is surely true in all cases and has nothing to do with where the galaxies lie in the BPT diagram as such.~~ [I DIDN’T SWITCH ANYTHING HERE. I DISAGREE, AND WE SAID SOMETHING SIMILAR IN THE ICA PAPER, BUT THERE NO NEED TO ADD A PARAGRAPH EXPLAINING IT.]

~~Paragraph starting: 'High ionization potential emission lines have historically signified AGN activity' - this is repeating the preceding paragraph, tidy up.~~ [COMBINE WITH PREVIOUS SENTENCE]

~~Page 4:~~

~~'without any signs of AGN' - What does this in particular mean? AGNs may be present in many of the samples, but not detected with current facilities.~~ [CLARIFIED]

~~Page 5:~~

~~'Follow-up work by Levesque et al (2010) ....' - This has been done many times before as well of course - for instance in Charlot & Longhetti (2001, Figures 1-3), Mas-Hesse & Kunth 1999, Mas-Hesse et al 1991, while the study in Levesque is clear and well done this phrasing makes it sound as if it was first done there which is misleading. Please be a bit more comprehensive in your referencing.~~ [ADDED REFERENCES]

~~'... has proven useful in fitting galaxy spectra with large He II / Hb values observed in the local universe' - This is a statement with some qualifications I would say - their modelling was not very successful at matching the large He II/Hb ratios (see also Guseva et al 2000), but it does indeed work for other strong lines (as has been demonstrated for other BCD-like galaxies by other authors as well).~~ [ADDED CITATION]

Page 9:

'as such, we have chosen the hardest SED possible for our baseline model.' - this goes back to my point among the major concerns above. I really do not see how your conclusion follows from the preceding argumentation. If you want to determine the conditions necessary, you surely need to choose the \_most correct\_ SED possible. Choosing an unrealistic SED would potentially lead you to make the wrong inferences about the conditions necessary.

Figure 1 - the discussion of this in the text does not match the labels on the sub-panels.

Page 10:

'overall hardness ... is fairly similar for non-rotating and rotating stars...' - I agree this is the case for the continuous SF models but I strongly disagree with this statement for the bursts - your panels have six orders of magnitude on the y-axis, any small shift is very

significant.

'.. to reach steady state' - please explain what steady state means here.

'... become much more apparent.' - Again, this statement is a bit confusing: for SSPs it is apparent also in Figure 1. Please tidy up.

'... stars begin to skip the WR phase' - 'Skip the WR phase' is a misleading phrasing - it makes it sound as if it goes on the same evolutionary track but just jump over the WR phase. I am sure this is not what you meant, but it is probably more correct to say: 'the less massive stars do not have sufficient mass-loss to enter the WR phase' or something like that.

'... the steady state Padova ... hardest ionizing spectrum' - firstly, do not use steady state to refer to the SED, and secondly this is surely correct, but this is because it is at solar metallicity and therefore has a vastly higher production of WR stars than at lower

metallicity. It is therefore not a suitable SED to use for lower metallicity simulations.

'... only included secular evolution ...' - what does secular evolution means here?

Page 12:

Where you refer to Shirazi & Brinchmann (2012) and Abel & Satypal you should really also refer also to Guseva et al (2000) who also studied He II/Hb in starbursting galaxies (following up from earlier work by Schaerer et al 1999), and also arguably Brinchmann, Kunth & Durret (2008) who also looked at He II/Hb and the relationship to WR stars

and also of relevance here is Thuan & Izotov (2005) who looked at Ne V, Fe V and He II emission in low metallicity galaxies.

'... peak Wlambda of ... is 5 times greater for Padova continuous evolution track than the Padova instantaneous evolution track.' – This is rather puzzling and is not really the normally expected case, certainly in the UV, if you compare the stellar populations at a

comparable time. The WR population in each case should be similar at say 5 Myr but the continuous SF model should have more bright stars contributing to the continuum than a SSP model - in which case the EW should always be higher in the SSP models.

Basically this is a statement about the relative life-time of the stars that dominate the energy production for the emission line and for those that dominate the continuum. It would be useful to understand better this statement as it is so surprising - for instance, at what time you do the comparison, over what time-range it holds etc.

~~Page 13:~~

~~'Full dust abundances are based on Orion (Baldwin et al. 1991)' – why is this relevant for high-z conditions? And are you specifying dust abundances or depletion patters or something else? Please give more details on this.~~ [CLARIFIED]

Page 15-16:

These are the pages where the ranges are given - I discuss my concerns

about this above.

~~Page 18: '... this does not pose too much concern as most of the emission lines we track do not optimally emit ... .' – But these are close to the densities that we generally find at low and high redshift. It is exceedingly rare to find HII regions with densities above 10^3 cm^-3. Firstly I do not think this is a problem - it is what happens, but the sentence should be rewritten.~~ [OR…JUST TAKEN OUT…]

'Note that the three studies ... parameter space that represent HII regions ... we also explore the more extreme conditions...' - I would recommend looking at some of the literature on low redshift analogs (e.g. Borthakur et al 2014; Brinchmann, Pettini & Charlot 2008; Liu et al 2008; Bian et al 2016). It is indeed true that something like Orion

is completely unsuitable for high-z work (or even comparing to extreme star-bursts in the local Universe), but there is a large body of work indicating that there are star-forming regions at low-z that are showing comparable conditions to those at high redshift. Stars do not change \_that\_ much with redshift. It is true that you cover a much large range of parameter space, but most of it is irrelevant for the application you have in mind.

~~Page 19: 'While some optical and infrared emission lines emit in these extreme regions, the efficiency of reprocessing is generally very low making emission lines weak.' - This is true, but be aware that for applications to low redshift star-forming galaxies this emission might be very relevant (not important for your specific goal though I admit).~~ [I DON’T QUITE UNDERSTAND THIS COMMENT. THIS PERTAINS TO HIGH-DENSITY ENVIRONMENTS BUT THE REFEREE TOLD US TO EXCLUDE THOSE SIMS…]

Page 24:

~~'do not predict ..., but create enough emission to be detectable by current optical instruments' - what does this mean? that is a completely non-quantitative statement and it must be made clearer. What are 'current instruments' and what are their limits? Furthermore He II 4686 (nebular) is often mixed with He II 4686 (WR-wind) and disentangling the two might also be challenging. Please make clear what you mean here.~~ [I ADDED SDSS SPECTROGRAPHS AND A REMARK ABOUT MIXED CONTRIBUTIONS…IS THIS OK?]

Page 25:

You comment on the collisional deexcitation of [O III] which renders 4959+5007/4363 less useful as a thermometer - this is correct, but not entirely relevant for star-forming galaxies as densities almost never reach these levels.

Page 26:

This section is also one where you need to discuss dust emission mechanisms and their effect on the equivalent widths as I comment on above.

Page 27:

~~'Taking these ratios on our grids indicate that our simulations have temperatures around 104 K with log(nH) ~ 3.0, which is consistent with Figure 3.' - What does this sentence mean? I understood your 'simulations' to be the Cloudy runs, but here that is clearly not the case - what simulations are you referring to? Please clarify!~~ [I THINK THIS WAS A SNARKY COMMENT ABOUT OUR VERBAGE…WHICH I THINK I’VE CORRECTED]

Page 28:

~~'high [Ne V] emission is likely due to AGN activity, however the simple presence of [Ne V] emission should not attributed to non-thermal excitation.' - this is not a sufficiently clear sentence. What does 'high' mean here? When (and how! see e.g. Thuan & Izotov 2005) should I conlcude it is AGN?~~ [ADDED A SENTENCE ABOUT WHEN YOU SHOULD QUESTION WHETHER A STARBUST IS THE SOLE EXCITATION SOURCE]

Page 30:

~~Equation 4: What is xi?~~ [THIS LED ME THROUGH A WORMHOLE OF LARGE WORD REVISION. SEE IF IT’S OK.]

~~'This pocket of no emission was neither present in our solar simulations nor in our subsolar simulations.' - So when is it present? This sentence makes little sense as written. Please clarify.~~ [WE ALREADY CLARIFIED THIS IN THE NEXT SENTENCE]

~~'(whose ionization potentials is similar to that of [O III] λ5007: 47.9 eV and 54.9 eV respectively)' - Why do you bring up the ionisation potential for O++ to O+++? [O III]5007 is a forbidden line so the ionisation to O+++ is not the relevant step - rather it is the ionisation from O+ to O++. You should also be able to determine what process dominates for C III 977 emission in this region by looking at the Cloudy output. Please fix & improve.~~ [OOPS…CORRECTED]

Page 35:

~~'as Ferland et al. (1996) discuss, He II λ1640 decreases with increasing Z due to the increased ....' - These days this is more usually phrased with respect to the incrased opacity in the stellar atmospheres and the change in WR star content which you do not discuss here at all. Ferland's discussion is of course correct, but only relevant for situations where the shape of the ionising continuum does not significantly change. Since there are many more WR stars at higher metallicities (due to the increased winds), the He II emission is also boosted significantly relative to low-Z, in contrast (but not~~

~~disagreement!) with Ferland's argument.~~ [I GUESS THIS IS TRUE, BUT IF WE START TALKING ABOUT VARIATIONS IN THE CONTINUUM THEN WE’LL BE ASKED WHY WE DIDN’T VARY IT WITH METALLICITY…]

~~'In regards to ....' - why do you bring this up? Your grid does not extend to <0.01 Z/Zsun. The whole paragraph is irrelevant where it is placed (the point is fair enough though).~~ [I JUST DELETED THIS PARAGRAPH SINCE WE’RE NO LONGER CONCERNED WITH HIGH-Z GALAXIES]

Page 37:

~~'It should also be noted that ([O II] λ3727 + [O III] λλ4959, 5007)/Hb acts as a metallicity indicator.' - This is true, and references should be given - e.g. Pagel et al 1979; Mc Gaugh 1991; Kewley & Ellison 2008 for an overview, many more exists.~~

~~'(Nagao, Maiolino and Marconi, 2006, Raiter et al. 2010).' – A surprising choice of references - this has been well known at least since McGaugh 1991 and while these two papers certainly are good, they are not particularly known for the R23 analysis.~~ [REFERENCES ADDED]

Page 38:

~~'Our predictions regarding the emission of fine structure lines are based on Hα emission, which is relatively flat across our grids' – I have absolutely no idea what you mean with this sentence, please clarify!~~ [I’M NOT SURE EITHER SO I DELETED IT.]

~~'Thus, we can only compare differences in the peak equivalent widths of [O I] 63 μm and [O III] 88 μm at constant phiH and nH values as indicators of differences in SFR. Otherwise, these differences should be interpreted as differences in emission based on the adopted Hand nH values. Observers should thus be cautious when using these fine-structure lines as indicators of SFR.' - Again, I have no idea what you are trying to say here, I can't even start to guess. Please clarify!~~ [I DELETED THE BIT ABOUT [O I] BUT LEFT IN [O III] AND CLARIFIED.]

Page 40:

~~Figure 6a (and 6b, 6c): The labels of the lines are Cloudy specific and not easily~~

~~understandable to a general reader. They should be changed to actually include what lines are considered. Also the shape of the plots with 4.5 orders of magnitude on the y-axis and very compressed vertically makes them very hard to read. A different aspect is needed to be able to read the figures properly.~~ [I DON’T AGREE. THE FIGURES SEEM FINE AND A LOT OF CLOUDY PAPERS USE LABELS SPECIFIC TO CLOUDY]

Page 42:

~~This discussion conflates the starburst age with the age of the galaxy. This is misleading and unlikely to be true physically.~~

~~'O-type stars tend to dominate the luminosity of starburst galaxies.' - It is more correct to talk about H II region - there is little reason to believe that a galaxy will form on time-scales < few Myr.~~

~~'The equivalent widths of many of the strong hydrogen recombination lines like Hα, Hβ, or Brγ can be used as age indicators because they measure the ratio of the young, ionizing over the old, non-ionizing stellar population.' - This is to some extent correct - this is for~~

~~instance discussed in Mas-Hesse & Kunth (1999) - it is an old result and some references would not go amiss here.~~ [REFERENCE ADDED]

Page 43:

~~'Geneva and Padova continuous tracks, however, continue to emit constantly across the 6-8 Myr range.' - Surely the tracks themselves do not emit! Please rephrase.~~ [VERBAGE CORRECTED.]

Page 46:

~~'The physical reason for this apparent contradiction is that dust makes a substantial contribution to the overall opacity in our dusty simulations, which decreases the availability of high-energy photons to ionize and excite the gas.' - This explanation makes some sense for Ne V and Ar IV, but not for Si II and Mg II which are both low~~

~~ionisation energy lines.~~ [THESE LINES ARE GONE SO THIS PARAGRAPH IS AS WELL]

~~A key factor here is likely dust depletion. Indeed the main effect of dust in HII regions is depletion of metals onto dust grains (e.g. Shields & Kennicutt 1995) and a discussion of depletion and its effects should enter here as well.~~ [ADDED PHOTOELECTRIC HEATING STATEMENT AND CITATION]

~~'Many of the equivalent widths of UV emission lines increase with the removal of dust since dust absorption peaks in the UV' - But in your model surely the dust attenuation of the continuum and the line is the same, so why should you see an effect on the EW?~~ [BECAUSE OUR EW IS RELATIVE TO THE INCIDENT CONTINUUM, THE EMERGENT CONTINUUM FROM THE CLOUD, BUT I DON’T SEE A REASON TO STATE THIS.]

'... while the region it emits across the LOC plane essentially disappears...' - It seems to expand significantly to my eyes?

~~'dust free models either get incorporated into the larger emission region in the plane or disappear, best seen with [S II] λ4078 and [S II] λ6720 ' - why?~~ [NO IONIZATION JUMP]

Page 48:

~~'Thus we agree with the conclusion that AGN contribution is needed for local [Ne V] 14 mum and 24 mum emission' - This is insufficient – you have not considered shocks, nor X-ray binaries, nor the effect of normal binaries or uncertainties in the SED-shape, so how can you make this conclusion?~~ [ADDED A STATEMENT ABOUT ADDITIONAL EXCITATION SOURCES]

~~'Thus, we suggest that perhaps there are low metallicity pockets within these local galaxies, which contribute to their overall He II λ4686 emission.' - I really do not understand how this statement follows from any of what you have written above. Please rewrite.~~ [IT SEEMS CLEAR TO ME?]

Page 50:

p 53:

The JWST comparison is confused and not sufficiently quantitative. While NIRCam has a grism, it operates at long-ish wavelengths (2.4µm-5µm) and will not be JWST main spectroscopic instrument. That will be NIRSpec and maybe you have mixed NIRSpec and NIRCam?

'With peak log(Wλ) around 2-3, these emission lines should be bright enough as well.' - for what? What exposure time, what assumptions about host galaxies, what SFR? There are no details and this part is not useful as it stands.

Page 54:

'We predict that C III λ977 and C IV λ1549....' - C IV might be, but why this CIII 977? It would be completely killed by the intervening IGM. Anything below 1216Å in the rest-frame is likely to be useless at high redshift due to IGM absorption.