MNRAS: MN-18-3727-MJ.R1

The manuscript by Smethurst et al. presents an open source code to obtain parametric representation of the quenched star formation history from galaxy spectra using MCMC. This code is the development of the approach proposed earlier by the same team (Smethurst et al. 2015). I'm finding particularly interesting the approach of detecting secondary minima in the parameter space.

My recommendation regarding this manuscript is a major revision. I also have to notice that the current manuscript has exact copies of some textual fragments from the 2015 paper, which should be removed.

The authors would like to thank the referee for an insightful report which has helped to clarify the paper for a reader. We respond inline to comments below.

I have two major points of criticism regarding the technique presented in the paper.

1. As a person who has been dealing with the full spectrum fitting for the last 15 years, my main question is "why?" Why to use an overly simplified approach, which exploits a minor fraction of available information in a spectrum instead of using it all? I understand that using MCMC for 4000+ individual pixels in a spectrum will not make the approach quick, but it's not a valid argument. When no intermediate-resolution models were available until 2003-2004 (Bruzual and Charlot; PEGASE-HR; later MILES) and computational power was the main bottleneck, it made sense to use line-strength indices or other "information compression" techniques (e.g MOPED) in order to use the most prominent spectral features. It does not nowadays in the light of development of stellar population and ISM models and data analysis techniques.

The statements from the introduction about "redundant" parts of the spectrum and "disruption" of full spectrum fit by low signal-to-noise are incorrect. No parts of the spectrum are redundant, and the "disruption" occurs only if the uncertainties are not correctly treated. Simple analysis done in Chilingarian (2009 MNRAS 394 1229) for intermediate-resolution spectra and then in Chilingarian et al. (2011) for high-resolution spectra demonstrated that about 3/4 of the useful age- and metallicity-sensitive information is ignored when dealing with Lick indices, in particular, no more than 20% of age-sensitive information is contained in the H-beta spectral index. Therefore, if the authors would like to proceed with their current approach, I would like to see an extended description of the analysis that demonstrates the distribution of the information in a spectrum, which is sensitive to the parameters of the quenched star formation history. The authors might follow the approach similar to that in Chilingarian (2009) but using partial derivatives of the likelihood function rather than chi2 or propose another mathematically valid approach.

It was never the authors intent to suggest that this method was in anyway superior to full spectral fitting. Indeed we agree with the referee's statement that our code is an oversimplified approach, but one which we hope will be complimentary to that of full spectral fitting. We have reworded our introduction to highlight how this method is intended to be complimentary to full spectral fitting by providing an alternate method for determining parameterised star formation histories, so that results derived using each method may be compared. We have added references to the discussion in Chilingarian et al. (2011) to our introduction, including the result that 75% of the age- and metallicity-sensitive information is ignored when considering only absorption indices. However, we note that we are particularly focussed on the rate at which quenching declines and therefore specifically target EW[Hα], HδA and Dn4000 features (see response to specific comments below) to derive this information. We marginalise over the age and metallicity of a galaxy in our method, therefore we are less concerned by information lost by excluding measurements of the continuum from our input sources. However, if a user wishes to include such information they can easily adapt the publicly available code to do so.

2. The choice of spectral features "from first principles". Generally speaking, the current model seems to lack several astrophysical phenomena and/or stellar population characteristic which may and likely will hamper the results of the analysis.

The most problematic is the use of H-alpha. The star formation is not the only source of H-alpha emission. Those can be related to active galactic nuclei (narrow-line regions in Seyferts, LINERs), shocks, late stages of stellar evolution (post-AGB, SNe remnants). I have not found a single mentioning of these phenomena in the paper, except the AGN as one of the reasons for quenching. By attributing the entire H-alpha flux one can make a serious overestimate of the current SFR. I see two possible solutions for this (maybe the authors will find something else): (i) doing a pre-selection based on emission-line ratios and rejecting everything that is out of the star-formation sequence on the BPT diagram; (ii) including models for non-SF related ionization (e.g. shocks) into the algorithm. The latter approach will likely require to include some additional [emission-line] indicators.

The D4000 and H-delta might provide reasonable age-related constraints, however, they are both sensitive to the alpha-enhancement of the stellar population and to the overall metallicity. The D4000 blue pseudo-continuum definition area is very sensitive to the carbon abundance, the overall index is also sensitive to internal extinction.

At the end, I would recommend at very least to add a discussion on how non-SFR related emission and non-solar alpha-abundances will affect the results of the code in a similar fashion to what is done for the different shapes of then quenching SFH.

The referee is correct in stating that the stellar spectra generated in SNITCH are done so assuming that star formation is the only source of ionising photons. We do not model for other ionising sources of photons. As stated in footnote 15, SNITCH was originally developed with a focus on quenching caused by AGN feedback. However, the authors had always intended to account for the contamination of the spectra by AGN when analysing the data, rather than in the model itself. We intend to apply SNITCH to IFU data cubes of AGN host galaxies by removing those spaxels contaminated by emission from the AGN - either broad line emission or narrow line emission identified using a BPT diagram (as also suggested by the referee). This will therefore be a task for our next paper which will describe how we have applied SNITCH to this data. We never intended to model for this in the spectra generated in SNITCH, however once again note that this could be adapted by a user. We thank the referee for bringing to our attention that this was not mentioned in the paper and so have added paragraphs to Section 2.2 and 2.3 highlighting this to the reader.

Unfortunately the Conroy FSPS models do not allow the α-abundances to be altered, so such an investigation into how non-solar α-abundances affect our results is beyond the scope of this work. However, it is possible for a user to conduct such an investigation using a customised version of SNITCH. We have stated this in Section 2.2 and footnote 8 encouraging an interested reader to conduct such an investigation with their own spectral generation code snippet.

Specific comments:

-- Everywhere in the manuscript: please re-read it carefully and correct minor problems such as references (Peng & et al.), style/phrasing in a number of places.

Apologies, these references had too many authors for the MNRAS style file and an error was raised during compiling due to the length of the string. We hope these can be corrected during the proof by MNRAS editors after acceptance.

-- Introduction, 1st sentence. There are many examples of techniques, which deal with specific features. The best-known is of course line-strength indices (e.g. Lick indices, see Worthey 1994 for the first calibration of these indicators to get quantitative information about stellar population parameters and Worthey et al. 1994 for the first application to real galaxies). Another example of a technique which tries to "compress" the information contained in a spectrum is MOPED (Heavens et al. 2004; Panter et al. 2004).

These references have been added to our rewritten introduction section.

-- Introduction, 2nd paragraph. While MaNGA and SAMI deal with "bundles of fibres" with exchangeable configurations, CALIFA used the general purpose IFU spectrograph PMAS-PPAK, where the fibre configuration is fixed so it is not correct to call it "a bundle of fibres".

The authors thank the referee for pointing out this important distinction. The text has been altered accordingly.

-- Section 2.1. Some paragraphs repeat word-to-word the contents of Section 3.1 from Smethurst et al. (2015), worth mentioning that the authors tell that they reproduce the description. First, there is no need to do that; second, in IOP journals (e.g. ApJ/ApJS) this would have triggered a plagiarism detection algorithm. While the first formula for the SFR is definitely useful, the description below it can be and should be summarized in 1-2 sentences.

The citation to Smethurst et al. (2015) is explicitly stated in Section 2.1 and the description has been reduced to a summary of the previous work. We thank the referee for pointing out that this would have triggered plagiarism algorithms.

-- Section 2.2, footnote 7. The statement that "the propagation of uncertainty would be unquantifiable" is not really true. In simple cases when no mergers were involved (e.g. dwarf galaxies) the "leaky box" model and "leaky box with infall" (see Kirby et al. 2013) can

be used and the chemical evolution equations can be analytically integrated (see Chilingarian and Asa'd 2018).

This footnote has been changed to state that this is possible and the relevant references added.

-- Section 2.3. While I clearly understand that the authors use the results of MaNGA DAP, I will notice here that a single Gaussian approximation of emission line profiles when the internal kinematics of a galaxy is spatially unresolved (as in SDSS) or under-resolved (as in MaNGA) is bad. This was the main motivation why we had to re-process the entire SDSS galaxy sample in order to obtain emission line fluxes from a non-parametric shape in the RCSED project (Chilingarian et al. 2017 ApJS).

The development of the MaNGA Data Access Pipeline, with particular focus on the emission line fitting is discussed in an upcoming paper by Belfiore et al. (in prep). The DAP provides both a gaussian and non-parametric fit to the emission lines. Whilst the expectation is for the non-parametric fit to be more robust, analysis done for the Belfiore paper has shown that the gaussian fit is appropriate for most spectra, except in the presence of broad line components (i.e. in Type 1 AGN which make up only 1% of the MaNGA galaxy sample). We have stated this in Section 2.3 for the benefit of those users who this will be an issue for.

-- Figure 1 is not very informative in its present form. I would recommend marking the features used by the code and described in the text.

We have adapted Figure 1 to show the locations of the spectral features used in this work and agree that the figure is now much more informative. We thank the referee for this suggestion.

-- Section 2.4. I am puzzled by the choice of Halpha equivalent width as a SFR indicator. The equivalent width by definition depends on the (stellar) continuum level while for the SFR what is important is the emission line flux. The equivalent width might be an option for specific SFR but not for the total SFR.

The flux in Hα probes the current SFR, whereas our focus in this work is on quenching, therefore we are more interested in the previous generation of stars. Like many other works (including Li et al. 2015, Wang et al. 2018 and Zick et al. 2018 to name a few), we chose to utilise the EW[Hα] over the Hα flux in order to probe the quenching star formation timescale. EW[Hα] measures the relative contribution of the Hα emission to the underlying continuum. Since the continuum is a proxy for stellar mass and the Hα emission arises around short-lived O and B stars, the EW[Hα] is ideal for probing recent changes to the SFR because it relates the SF in the past ~100 Myr to the total integrated SF over the galaxy's lifetime. Combining this measurement with that of H**δ**A which peaks when A stars dominate, and Dn4000 which is sensitive to older stars, allows for all the different star formation timescales to be probed by using indicators of stellar populations of different ages. This discussion has been added to Section 2.4 to make the choice of EW[Hα] clearer to the reader.

-- Section 2.4. Dn4000 does depend on the internal extinction because its pseudo-

continuum definition regions are quite far apart (150A in the Balogh et al. 1999 definition, which is 3.75% of the wavelength).

This has been added to Section 2.4.

-- Section 2.4. The H-beta index in many galaxies will be polluted with emission, so it might not be a good indicator unless it has been corrected for emission line flux (and this correction is model dependent)

The referee is correct in this statement, which is why in SNITCH we subtract the fitted emission line flux from the model spectra (in the same way that the observed spectra are measured in MaNGA) before measuring the absorption features. This is stated in point (iii) of Section 2.3. Although this subtraction is model dependent, this issue is no longer troublesome since we use the same spectral fitting procedure to measure the spectral features in both the observed and synthetic spectra generated by SNITCH. We have stressed this to the reader in Section 2.3.

-- Section 2.5. Some sentences in are either identical or very similar to those in Smethurst et al. (2015) section 3.2. There is no need to repeat your own work.

These sentences in the description of the MCMC method have been reworded to avoid repetition with Smethurst et al. (2015)

Aside

We would like to note to the referee that an author has been added to this work post submission. This was due to a delay in the confirmation of an external collaborator request to the SDSS team.