CUME 424, April 7, 2018

The following cume is related to the paper “Ionization processes in a local analog of distant clumpy galaxies: VLT MUSE IFU spectroscopy and FORS deep images of the TDG NGC 5291N”, by Fensch et al., 2016, A&A 585, A79.

To start, I suggest to only read the abstract and Section 1, and then begin to look at the questions as they refer to specific sections of the paper.

Most questions are 5 points unless otherwise indicated. Passing grade is expected to be 75%.

*This cume closely follows my ISM class in the majority of the questions.*

I. First a few questions on the observations in Section 2.

a. What is a spaxel?

*A one pixel spectrum*

b. What is the advantage and what might be a disadvantage of “binning” the data. Is there a disadvantage in this particular situation? (Provide an answer that is more specific than the motivation the authors give in the middle section of the right hand column in Section 2.1)

*Binning is done to increase S/N for emission that is more extended than a single pixel. Given that the seeing was about 0.8”, and the original pixels were 0.2” there was no major disadvantage to binning (although there is a tad undersampling after the rebinning) and mostly the advantage of increasing the S/N. For independent pixels with a Gaussian noise distribution, S/N increases as the sqrt of the number of pixels if they all had the same noise per pixel.*

c. (10 pts) In section 2.1, the paper mentions that the [SII]6717/6731 line ratio is sensitive to the electron density. Why is that so? You might draw a sketch of the energy diagram. Discuss by which process(es) the lines may be excited and de-excited and how that then may provide information on the density. Also discuss if this line ratio is sensitive to temperature, and why it is or isn't.

*These lines originate from two closely spaced upper energy levels down to a lower energy level. The excitation of the levels is dominated by collisions with electrons. The de-excitation is either by collisions or spontaneous emission. The probabilities for the de-excitation hence depend on the electron density. Since the upper energy levels are closely spaced, there is no strong dependence on electron temperature: if one level can be excited by collisions, so can the other.*

d. Consider Figure 1. The flux scale seems to be given in a unit that seems to miss something, given what they plot. What would you have expected to be the unit given what is plotted on the x-scale? What might they have done to arrive at their unit?

*The figure shows a spectrum of flux against wavelength. One would therefore expect the flux unit to be erg/cm2/s/Angstrom. But the "per Angstrom" is missing. Most likely the authors multiplied each spaxel in wavelength direction by the number of Angstroms per pixel, although they don't discuss that. They should have then listed the unit as per pixel, but don't do that either.*

II. Now some questions on the results

a. (10 pts) In Section 3.1, the paper discusses the dust extinction and corrections for it. Describe which geometry for dust and emission the authors assume in their method for correcting for extinction. Describe how the method works, and how the extinction corrections can then be applied to the spectrum at all wavelengths. Describe carefully what is involved and what has to be assumed.

*They use the typical "Balmer decrement" method. This assumes a geometry of a foreground dust screen that is changing the line ratios in the HII region spectrum according to a particular dust extinction law. One has to assume the shape of the extinction law. The observed Balmer line ratios can then be related to the theoretical dust free "CASE B" ratios, which are fixed, to derive the extinction at e.g. Halpha. To apply it to the rest of the spectrum one then takes this extinction value and includes the shape of the extinction law with wavelength to correct the entire spectrum.*

b. Calculate the extinction at Halpha in mag for an Halpha/Hbeta ratio of 5. Assume that extinction law varies with 1/wavelength.

*The intrinsic ratio of the luminosities is 2.86*

$L_{obs}$ (H) / $L_{obs}$ (H) = 5 = [$L_0(H\alpha)\ e^{-(\tau H\alpha)}$] / [$L_0(H\beta)\ e^{-(\tau H\beta)}$]
And $\tau_{H\alpha} = \tau_{H\beta}/1.35$ from the wavelength dependence of the extinction law.

Solve for ($\tau_{H\alpha}$): 1.60, producing $A_{H\alpha}$ of 1.73

The following two questions relate to Section 3.2.

b. Consider the distribution of emission line ratios seen in Figure 5. One can clearly see differences in the spatial distributions of the different line ratios. Provide a qualitative, physical motivation for the behavior of the changes visible between the spatial distributions of e.g. [OIII]/H-beta versus that [SII]/H-alpha.

*The behavior shows that [OIII]/H-beta is strong near the brightest regions and [SII]/Halpha is strong in the faintest regions. This is in accord with a view where ionization happens by massive stars. These can doubly ionize oxygen close in (and hence also sulphur), while the lower ionization species are stronger further out once the stars runs out of high energy photons.*

c. Is the presence of a relatively strong [OI]6300 Angstrom line in HII regions typical? If so, why, if not, why not?

*The ionization potential of oxygen is very close to that of hydrogen, so it is not expected to see strong [OI] emission as most oxygen should be ionized.*

d. Section 3.3 introduces the "equivalent width" in H-beta. Show with a sketch and an equation how that is defined. Why would the emission line EW somehow be related to "the age of a starburst episode". Provide a qualitative motivation for that.

*Standard sketch, I do want to see an emission line EW here and not an absorption line EW. The EW is related to the age because the continuum light is built up as the starburst ages while the emission line flux goes down, so the EW is expected to go down with age.*

e. Consider Section 4.2. The authors discuss the possible origin of the blue continuum light they detect. They note that in co-added spectra of the regions of this light they do not see any stellar absorption lines and that this places strong limits on the ages of the stars. Why does this place limits on the age? (Hint: what absorption lines might they be most likely to detect given their discussion in that section and how would that limit the age?)

*They were probably hoping to see an "B or A-star-type" spectrum which would have strong Balmer absorption lines and might indicate a typical "post starburst" environment. They also looked for fainter MgIIb lines (also marked in Figure 15), which might provide evidence for a yet older population.*

f. In section 4.1.2 the authors write in the $4^{th}$ paragraph: "The velocity dispersion map of the ISM was computed from…We subtracted a constant……" Is that in fact correct? Calculate the velocity dispersion if the observed FWHM of the Halpha line were 4 Angstrom while the spectral resolution would correspond to a FWHM of 3 Angstrom.

*The FWHM values add in quadrature, not linearly, under a convolution. So the actual line width is sqrt($4^2 - 3^2$) Angstrom, or 2.6 Angstrom. Sigma then would be 2.35 smaller than that, so about 1 Angstrom or 45 km/s using Doppler formula.*

III. On the overall interpretation.

The authors refer to the object as "TDG". Do you agree the object is in fact a dwarf galaxy? Present arguments for and against. What else could it be?

*This seems to be a knot in a tidal arm segment with no evidence it is a separate galaxy (no dark matter, no older stellar population). The authors discuss much of this in Section 1. The results in the paper do not give stronger evidence that it is a separate dwarf galaxy, I think.*