

Cume 410, October 29, 2016, given by R. Walterbos

This cume is based on the paper: "Localized Starbursts in Dwarf Galaxies Produced by Impact of Low Metallicity Cosmic Gas Clouds", by Sánchez Almeida et al., Ap J 810, L15.

Each (sub) question is worth 5 points, except 10 pts for 3b and 4a, for a total of 85 points. Expected passing grade is 75%.

Use calculators only for calculations, not for stored formula.

1. Let us first get a handle on some relevant numbers that are not specifically stated in the paper.

1a. The slit width is  $1''$ . Calculate what that corresponds to in pc at the distance of the first galaxy in Table 1.

*Straightforward calculation from the information given in Table 1.*

1b. Is the HII region in the first galaxy in Table 1 spatially resolved by the observations presented in the paper? How do you verify that?

*Typical seeing is stated at  $1''$ . Scaling the size in Table 1, the HII region would be about  $1.5''$  in angular size, so barely resolved.*

2a. The authors specify the spectral dispersion of the spectrograph. Explain what we mean with that concept.

*The dispersion of the spectrograph states how strongly the light is spread out in wavelength by the dispersing element. It is usually specified in Angstroms per pixel or Angstroms per mm.*

2b. Explain how dispersion of light may be achieved in an optical spectrograph, and give an example of a common type of dispersing element in a modern spectrograph.

*The light is collimated and then dispersed by a grating. The principle is that the grating introduces differences in path length for light of different wavelengths and this produces dispersion through the destructive and constructive interference of light. The dispersion is determined by the number of lines per mm on the grating. The more lines per mm, the higher the dispersion of the grating.*

2c. The "spectral resolution" of a spectrograph is usually measured in units of Ångström. (It is not the same as "resolving power" which is another term you may see; that one is dimensionless). How is the dispersion of the spectrograph related to the spectral resolution? (Phrasing this in another way, for a properly designed

spectrograph, if I know the dispersion what would the spectral resolution be? Think of properly sampled signals).

*It is not exactly the same. The spectral resolution is measured on the spectra as the FWHM of an intrinsically narrow spectral line. Generally, for a properly focused spectrograph and proper sampling in the focal plane the spectral resolution is about 2 to 2.5 times the dispersion.*

2d. The paper also states what the slit width is. The spectral resolution of a spectrograph may also be affected by the slit width. Why and how? (Hint: what would happen if there were no slit in the light path?)

*A wider slit will lead to overlapping of spectra, from different regions across the slit, on the detector plane and therefore the resolution generally decreases linearly with increasing slit width for extended sources. (A wider slit also lets in more contribution from the sky which may add noise if seeing is better than slit width.)*

3. In this problem we will verify that the rotational time scales for typical galaxies like this are indeed of order a few hundred million years as stated in the paper.

3a. To do this, you will need to know the typical size and mass of these types of galaxies. This information can be estimated from the text and figures given in the paper. Do this, and explain how you got them.

*We can get the size in arcsec of galaxy 1 in Figure 1 from the scale given in the figure. We can translate that to a linear scale. We can get the stellar mass from the data in Table 1. Adding a correction for dark matter and/or gas mass for full credit.*

3b. (10 pts). Calculate the rotational period for an object in circular motion in the outskirts of the galaxies, the regions where the luminous HII regions studied here are typically found.

*This is simply from circular motion, assuming a spherically enclosed mass, and turning that into an orbital period.*

4a. (10 pts) Describe how the  $H\alpha$  luminosity can be used to estimate the star formation rate (SFR) in a galaxy. The paper describes this in one sentence in Section 3 but I want a bit more detail here. What is the physical connection between massive stars and  $H\alpha$  emission? How is that connection translated to a star formation rate? Describe what other assumptions or extrapolations have to be assumed to get to a total SFR.

*The paper gives the basic steps to connect  $H\alpha$  to massive stars but I am looking for more detail than given there. Essentially, we are counting Lyman continuum photons in  $H\alpha$ . To get a SFR we must then include the fact that these massive stars have short*

*lives, assume some steady state, and extrapolate to a SFR over all masses by invoking an initial mass function for the stars.*

4b. What is mean by the SFR density or “surface SFR” as the authors call it?

*This is simply the SFR normalized by area. The authors apply this very locally, and get very high SFR densities but it is because they do this on the scale of the single bright HII regions.*

5. In this problem we consider the results on the metallicities described in the paper.

a. The authors make the statement that the host galaxies have 3 to 10 times higher metallicity and 10 to 100 times lower “surface SFR” than the luminous HII regions in them. Where can we find the evidence for this information in the paper?

*See e.g. the labeling of the axes in Figure 3 and the data points in that figure.*

b. What is mean with a closed box model and what is the alternative the authors consider?

*A closed box model in chemical evolution is a model in which no gas enters or leaves the system once star formation begins. The alternative is an outflow model.*

c. Why does the closed box model produce a higher metallicity over time than the alternative they consider to that model?

*In the closed box model the gas continues to be enriched with metals as stars form and evolve, the outflow model allows metal rich gas from evolved stars to be driven out of the galaxies.*

6a. For this problem we will consider the results and analysis in the paper. Review the main reasoning the authors provided for their principal conclusion, that they have evidence for accretion.

6b. Discuss in a few sentences what you think of the analysis. Can you identify any weak or confusing points, or any assumptions or approaches the authors adopted that may be used to criticize their main conclusion. Relevant figures to consider here include 1 and 4.

*Note e.g. this choice in the analysis: they pick the lowest abundance measured as the abundance of the SB HII region and the highest average over 2.5” as that of the galaxy. In other words, they potentially bias their measurements to the two extremes. Also, the fainter regions have worse S/N (figure 1) and the ionization modeling they need to do to get abundances could be affected by what type of environment they are modeling.*

*Figure 4 shows another potential problem related to this. All their galaxies appear metal rich compared to the green region; that also suggests they may have a bias in assigning too high metallicities to the galaxies thereby exaggerating the difference in abundance between HII regions and overall galaxy. In the introduction they claim that the XMP galaxies are less than 0.1 solar. Their own data in Figure 4 seem to dispute this. They seem to claim that the low metallicities derived for such small dwarfs are biased by overly luminous metal poor HII regions and that the galaxies themselves are all more metal rich. If so, why would other non XMP dwarfs in the green zone in Figure 4 be so metal poor?*

1a  $1'' = \frac{1}{3600 \times 57.3} \text{ rad} = 4.85 \times 10^{-6} \text{ rad}$

$\frac{x}{D} = 4.85 \times 10^{-6} \text{ rad} \rightarrow x = 128 \text{ pc}$

$D = 26.4 \text{ Mpc}$

1b Size quoted:  $0.18 \pm 0.03 \text{ kpc}$

This is  $\frac{180}{128} = 1.4$

Seems:  $1''$

gas mass: see text!

3a Stellar mass, table 1:  $\log M_{\text{ke}} = 7.53$  (J 1132 + 57)

b radius (fig 1):  $\sim \frac{26 \text{ mm}}{6 \text{ mm}} \times \frac{10''}{2} = 22''$

$R = 2.40 \text{ kpc}$

$D = 22.5 \text{ Mpc}$   $1'' = 0.109 \text{ kpc}$

Dark Matter? Not that far out. Pick factor 10  
Total mass:  $3.39 \times 10^8 M_{\odot}$

$v_c = \sqrt{\frac{GM}{R}} = \sqrt{\frac{6.67 \times 10^{-8} \times 3.39 \times 10^8 \times 2 \times 10^{33}}{2.4 \times 3.086 \times 10^{21}}} \frac{\text{cm}}{\text{s}}$

$= 2.97 \times 10^6 \frac{\text{cm}}{\text{s}} = 24.7 \frac{\text{km}}{\text{s}}$

Orbital period:

$P = \frac{2\pi R}{v_c} = \frac{2\pi (2.40) 3.086 \times 10^{21}}{24.7 \times 10^5} =$

$= 1.88 \times 10^{16} \text{ sec} = \underline{\underline{6.0 \times 10^8 \text{ yrs}}}$

