Ludwigs-Maximilians-Universität München
Fakultät für Physik
Statistical Methods - An Introduction
Problemsheet 3 (SS12)

To be submitted on May, 7th, 2012 to jochen.weller@usm.lmu.de.

Messier 100

M100 (NGC4321) is a bright (apparent magnitude in V = 10.1) nearby grand design spiral galaxy [type SABbc(s)], discovered in 1781. An image from the Hubble Space Telescope (HST) (`www.stsci.edu/hst`) can be seen in Fig. 1.

A high-resolution spectrum of the central region taken with the Space Telescope Imaging Spectrograph (STIS) (`www.stsci.edu/hst/stis`) on HST is shown in Fig. 2. This observed-frame spectrum is provided in the file `M100_spec.txt`.

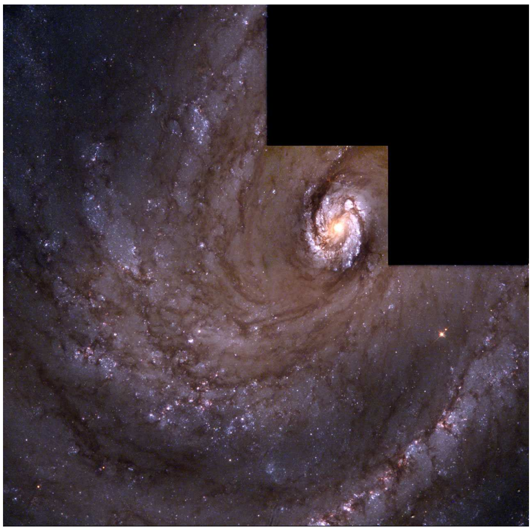

Figure 1: The M100 galaxy with the HST (credit: J. Trauger, JPL and NASA/ESA).

The five most prominent emission lines are in the order: [NII]6548, Hα,

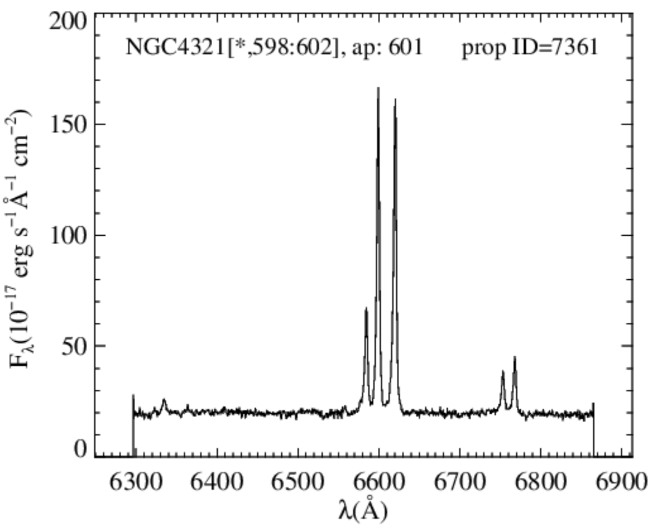

Figure 2: The observed-frame spectrum of the M100 galaxy with the Space Telescope Imaging Spectrograph (STIS) on HST.

[NII]6583, [SII]6716 and [SII]6731.

1. The first step is to subtract the continuum of the spectrum. Select the part of the data *away* from the emission lines, and fit a straight line through these data points. Assume for the uncertainties on the fluxes a relative error of 2%. The intercept of this straight line will be the continuum flux to subtract from the whole spectrum.

2. After subtracting the continuum, select from the provided data the Hα line. Using a Gaussian template, fit the amplitude, median and r.m.s. for this line. Assume for the uncertainties on the fluxes a relative error of 2%. *Hint:* you can just fix the amplitude from the highest data point in the line.

3. The wavelength of the spectrum has been shifted from the emitted to the observed frame due to the motion of this galaxy. This is mostly due to the Hubble expansion of the Universe. From the previous step, using the fitted median of the Gaussian, derive the distance to this galaxy in redshift and in Megaparsec (neglecting the peculiar velocity of this galaxy and assuming pure Hubble flow). *Hints:* the redshift is

defined as $z \equiv \lambda_{\rm obs}/\lambda_{\rm emitted} - 1$, and an approximation of the distance, valid at $z < 1$, is given by $cz/H_0 \simeq D$, where the Hubble constant is $H_0 \simeq 70$ km/s/Mpc.

4. As described in the previous point, additional local velocities of the emitting regions may sum up with the Hubble recession. In particular, these emission lines are produced by the gas in the observed central region of the galaxy, which is rapidly rotating. The faster the average rotation, the more noise will be added on the line, which will spread and become broader. Estimate the velocity dispersion of the gas in this region of M100 using the variance of the Gaussian fitted in the first step. *Hints:* the relationship between fluctuations in observed wavelength and local velocity is approximately $\delta v \simeq c\,\delta\lambda/\lambda$.

Bonus points: some galaxies from SDSS

The Sloan Digital Sky Survey (SDSS) (`www.sdss3.org`) is the state-of-the-art galaxy survey for cosmology, while also having a significant impact on galaxy studies. It contains more than 100 million galaxies; spectra are being measured for an increasing fraction of them. A few images can be seen in Fig. 3.

1. By looking at the spectra of the following galaxies in Fig. 4, where the most important emission and absorption lines have already been identified, roughly estimate their distance (redshift).

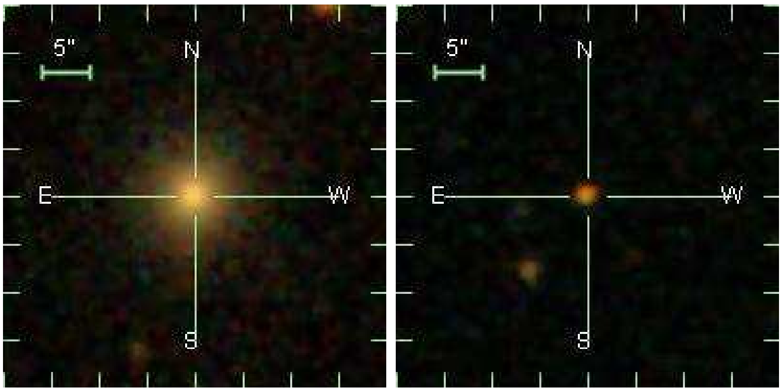

Figure 3: Some example galaxies from SDSS (credit: the SDSS collaboration).

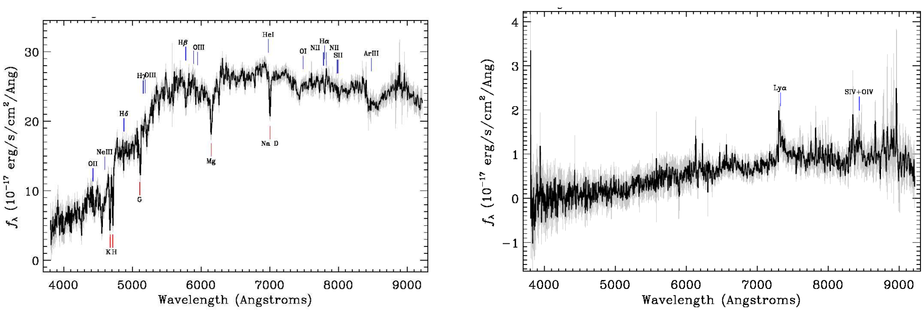

Figure 4: The observed-frame spectrum of some SDSS galaxies. The most prominent lines are marked.