

## Homework 5 (with the help of Fabio Bresolin)

1. As part of our project on blue supergiant stars in nearby galaxies we have acquired medium-resolution spectra of a few dozen stars in the beautiful spiral galaxy NGC 300 at a distance of 2 Mpc (that's about 3 times as far as the Andromeda galaxy) with one of the four 8-m units of the ESO Very Large Telescope in Chile.



In order to analyze such spectra, the first step required is to classify them. In this exercise you will use a simple IDL program to determine the spectral type of 12 stars in NGC 300. Apart from your two well-behaved instructors, you are among the first ever to carry out this kind of stellar classification at such large distances. If that helps to increase your self-esteem, remember, these objects are at about 1,000 times the distance of the objects classified by Annie Jump Cannon at Harvard in the early 1900.

## Homework 5

Retrieve the IDL routine and associated files at

<http://ezzelino.ifa.hawaii.edu/~bresolin/teaching/astro631/classification.tar.gz>

Once downloaded the file, unzip it and untar it (on a unix/linux machine):

```
gunzip -c classification.tar.gz | tar xovf -
```

To run the classification program, just run IDL. At the prompt type:

```
.r forsg (don't forget the dot)
```

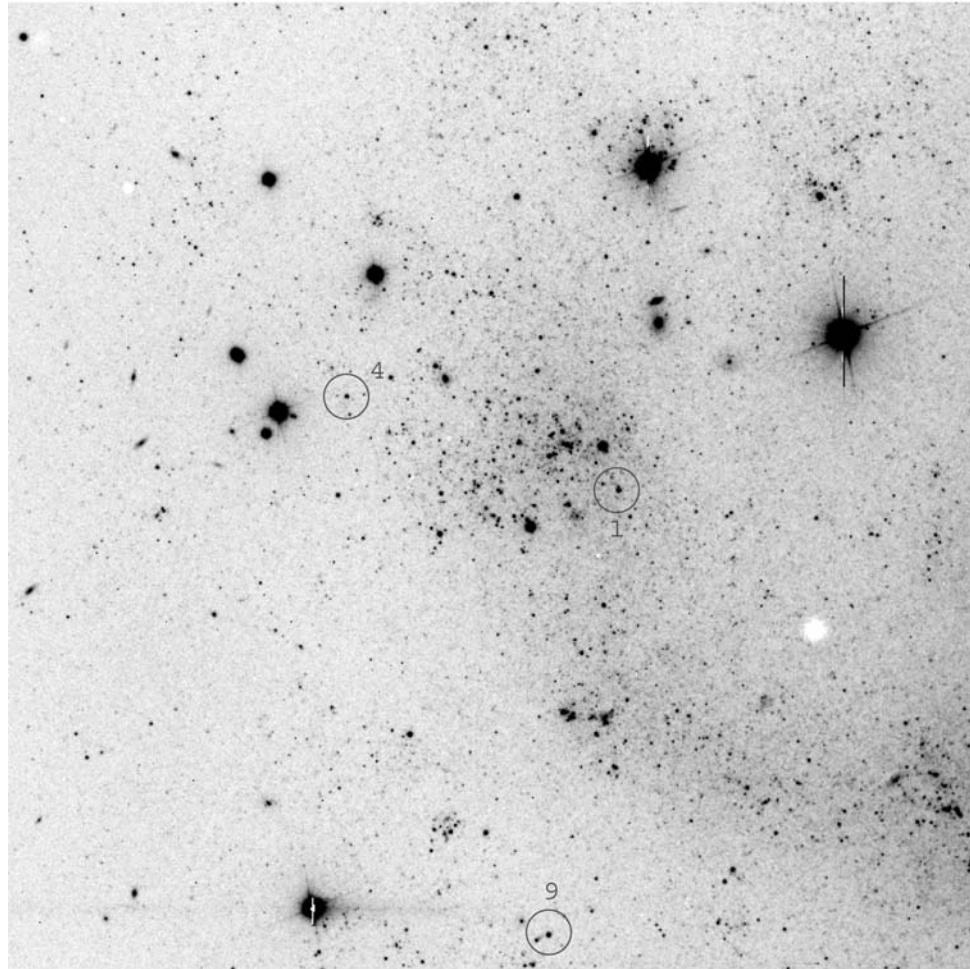
```
forsg
```

When the program screen starts up you can: a) click on a slit number (from 1 to 12) on the left of the black and evil window, then b) click on a spectral type (from O9.5 to F2) at the top. A plot of the NGC 300 supergiant star will appear, bracketed by the spectra of two Galactic supergiants of contiguous spectral type.

You can change the wavelength scale, radial velocity, and add line identification labels if that pleases you. You can also check the effect of different metallicity by using supergiant templates from the Small Magellanic Cloud (SMC) (B0 – B8 only), for which the metallicity is reduced by approximately a factor of 5 relative to the Galactic stars.

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Here's an example of what some of these stars look like in a 7 x 7 arcmin portion of the galaxy





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Produce a nice-looking table giving your estimate of the spectral type for each of the twelve stars. Since these are real spectra of stars at different magnitudes, lying in different portions of a distant galaxy, you will experiment with data of differing signal-to-noise ratios, and with possible contamination by nearby objects (stars, HII regions). If you notice something not quite 'standard', make a note of it.

(6 points)

2. The element silicon produces spectral lines in the optical spectra of all spectral types from K to O. The lines appear in different ionization stages from I to IV. The following table gives the information about the observed lines. Excitation energy and statistical weight correspond to the lower level of the spectral line.

Using the Boltzmann formula

$$\log \frac{n_{ij}}{n_{1j}} = \log \frac{g_{ij}}{g_{1j}} - \frac{5040}{T} E_{ij} \text{ (eV)}$$

and the Saha formula

$$\log \frac{n_{j+1}}{n_j} = -0.1761 - \log P_e + \log \frac{U_{j+1}}{U_j} + 2.5 \log T - \frac{5040}{T} E_j \text{ (eV)}$$



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ionization stage	line $\lambda$ (Å)	ionization energy (eV)	partition function	excitation energy (eV)	statistical weight
Si I	3905.53	8.12	10.2	1.90	1
II	4128.04 4130.88	16.27	6	9.80	10
III	4552.65 4567.87 4574.78	33.35	1	18.94	3
IV	4088.86 4116.10	44.93	2	23.93	2
V	-	169	1	-	-

and with  $P_e = n_e k T$  ( $k = 1.36 \times 10^{-16}$  erg K<sup>-1</sup>) calculate and plot

$$\log \frac{n_{ij}}{\sum n_j}$$

as a function of temperature  $T$  (from 3,000 K to 50,000 K) for  $n_e = 10^{14}$  cm<sup>-3</sup> (dwarfs) and  $n_e = 10^{11}$  cm<sup>-3</sup> (extreme supergiants).

(4 points)

**Please return homework on Monday, October 31 (costume required)**