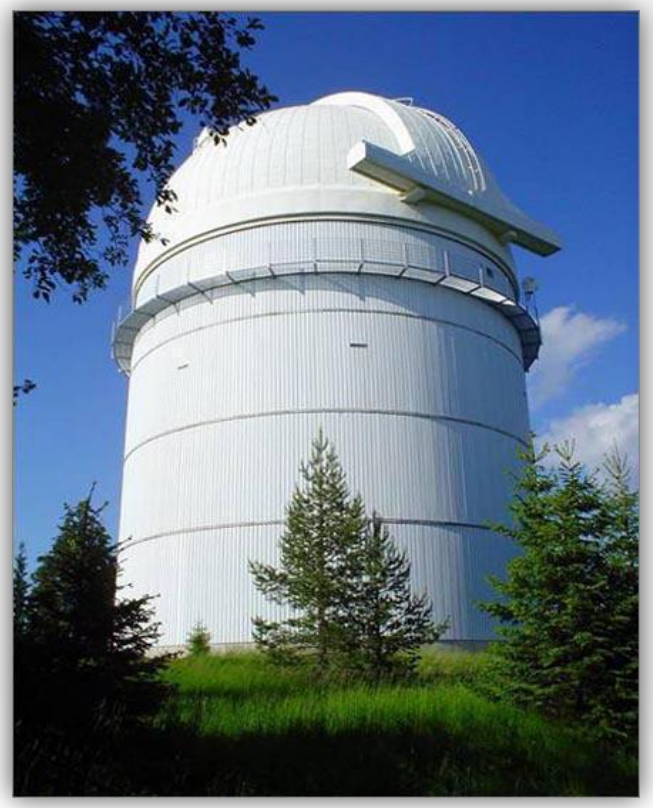
A GLANCE AT THE BEGINNING OF THE UNIVERSE

FOREIGN LANGUAGE SCHOOL
"NIKOLA I. VAPTSAROV"
SHUMEN, BULGARIA

Based on observations with the 2-m RCC telescope of Rozhen National Astronomical Observatory operated by Institute of Astronomy, Bulgarian Academy of Sciences.



http://www.nao-rozhen.org

Photo: P. Markishky

In 2011 a group of students from our school won a prize in the competition "Catch a star 2011". The prize was an one-hour observation with 2-m RCC telescope of the Bulgarian National Astronomical Observatory – Rozhen.

We decided to observe the galaxies NGC 4258 and NGC4725.

Our idea was:

- To measure the redshift
- To determine the Hubble constant
- To find the age of the Universe

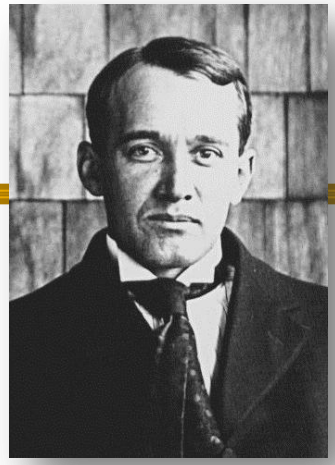
TIMELINE

1912

Henrietta Leavitt discovered the relation between the luminosity and the period of Cepheids (variable stars). Using this relation it is possible to measure the distance to galaxies with Cepheids.

1923

Vesto Slipher was the first to observe the shift of spectral lines in galaxies, making him the discoverer of galactic redshifts. This allows us to measure the speed at which galaxies are receding from Earth.



1924

Edwin Hubble identified Cepheid variables in Andromeda Nebula. He proved conclusively that these nebulae were too distant to be part of the Milky Way and were, in fact, entire galaxies outside our own.

1927

Georges Lemaître was the first to apply Albert Einstein's theory of general relativity to cosmology. He proved that the theory of the expansion of the Universe does not contradict the theory of General relativity.

1929

Edwin Hubble formulated the empirical Redshift Distance Law of galaxies, nowadays termed simply Hubble's law.

1965

Arno Penzias Robert and Wilson detected the microwave background radiation. Its existence has been predicted by George Gamow in 1948. This discovery proves the Big Bang theory.

Which means: the Universe has a beginning!!!

Some information:

$$\frac{v}{c} = \frac{\Delta\lambda}{\lambda}$$

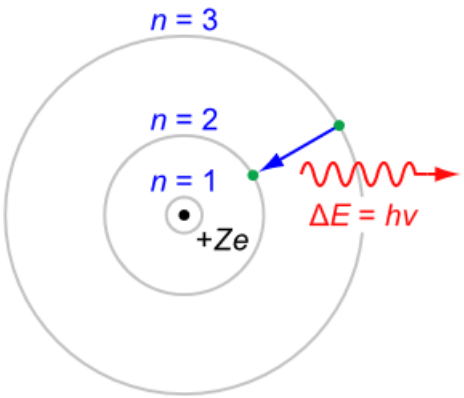
v – velocity of radiating object;
c - speed of light;
Δλ - red or blue shift;
λ - wavelength

$v = H.r$

V - velocity of galaxy;
H - Hubble constant;
r - distance to the galaxy;

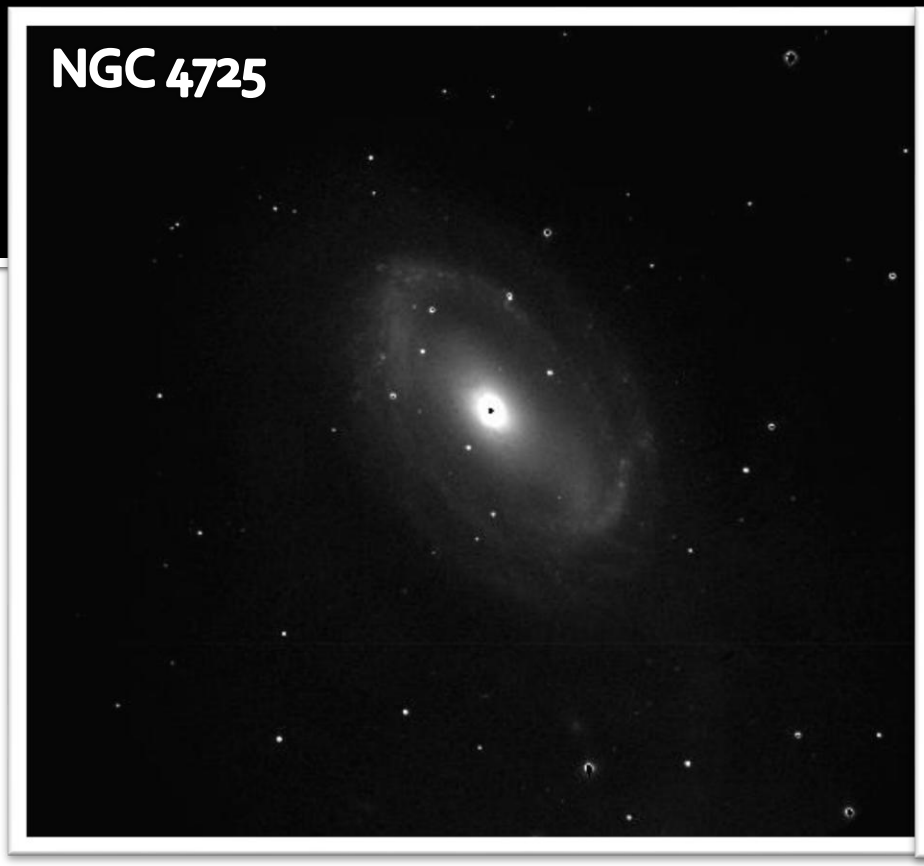
$$t = \frac{1}{H}$$

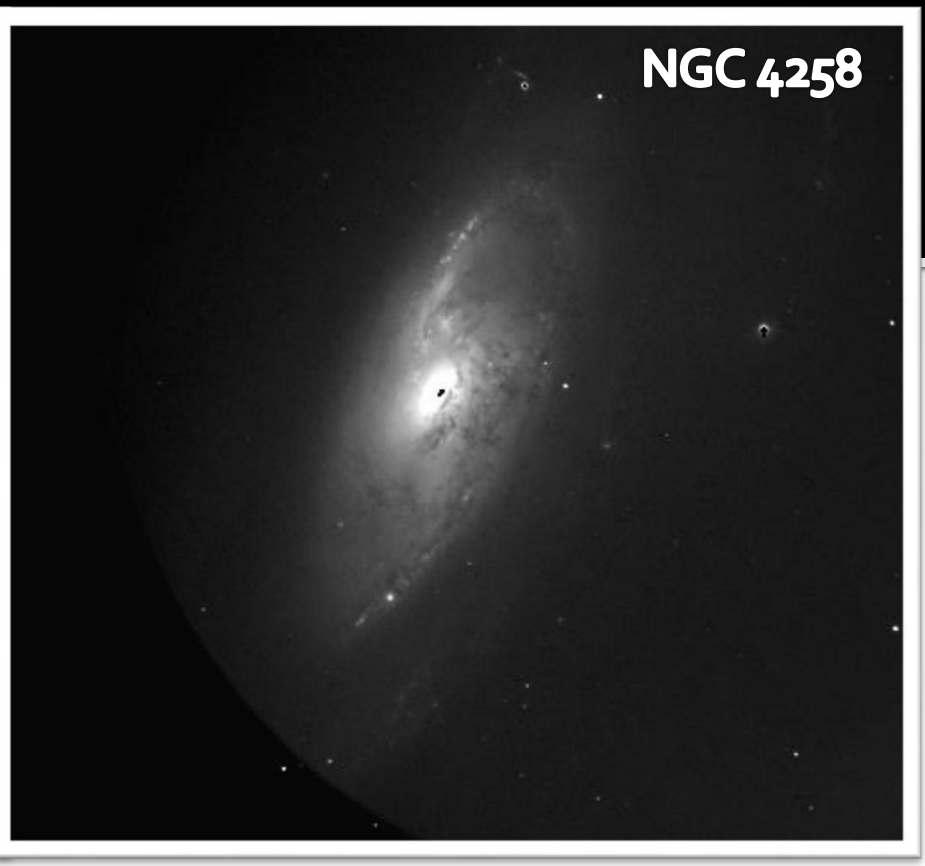
t - the age of the Universe;



The Hα line are photons, emitted in the electron transition from n =3 to n = 2 in hydrogen atom.
Hβ line - from n = 4 to n = 2.
The process is reversible for both Hα and Hβ's lines.

https://en.wikipedia.org/wiki/H-alpha



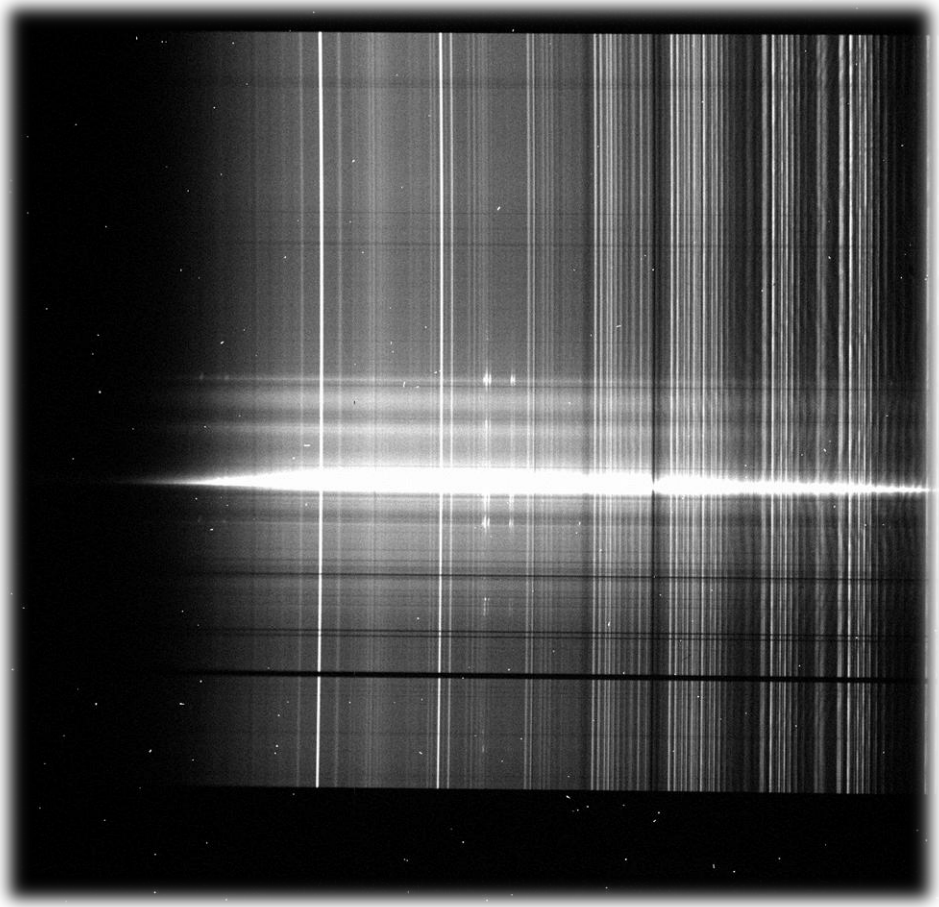


On 25 June , 2012 the spectra of galaxies were taken. The video conference, organized by Dr. Galin Borisov allowed the students to observe the process from the beginning until the end.

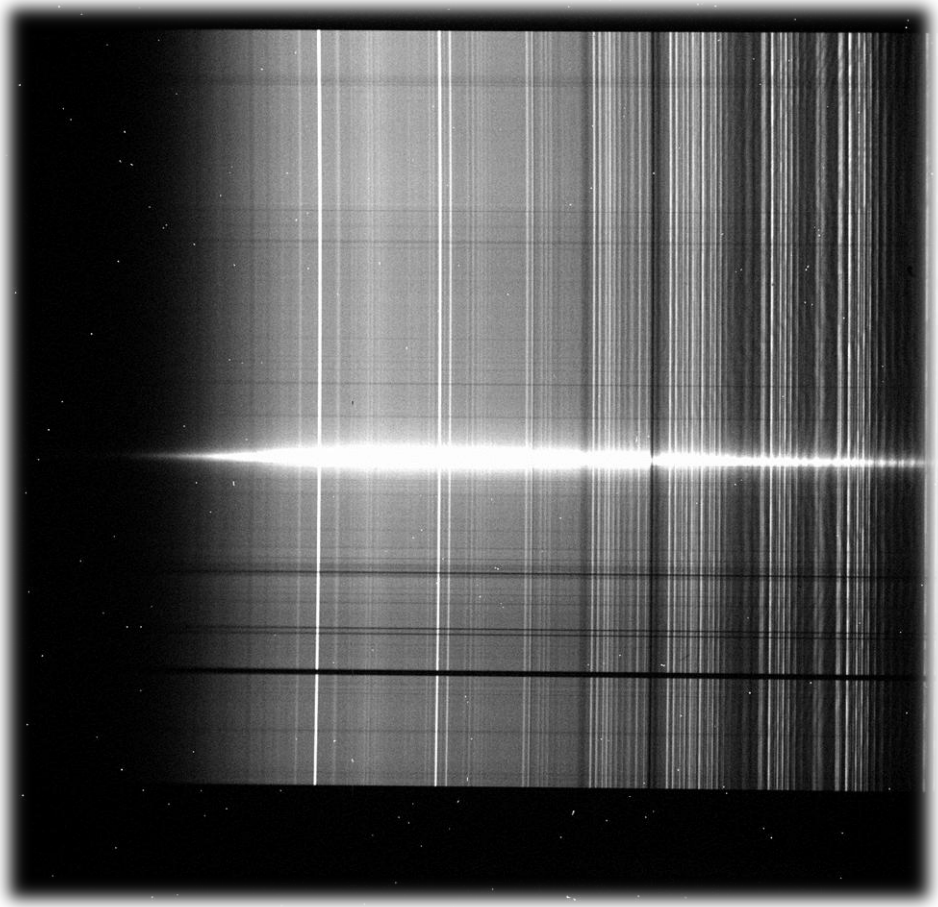
NGC 4258 is a spiral galaxy in the constellation Canes Venatici. It is at a distance of about 22 to 25 million light-years away from Earth.

NGC 4725 is a bared spiral galaxy with a single arm located 40 million light-years away in Coma Berenices. (7)

These are the unprocessed spectra of the both galaxies.



NGC4258



NGC4725

Processing the spectrums includes deriving wave length and true intensity from the images. Therefore a star- spectrophotometric standart is used - 58 Aquilae.

This process goes beyond our abilities. Because of that Dr. Borisov helped us with processing the spectrums.

Here is the data

Microsoft Excel - n4258_

File Edit View Insert

Calibri 11

D13

	A	B
1	λ ; 10^{-10}m	spr
2	4501,39	107443
3	4505,72	99093,5
4	4510,06	100358
5	4514,4	98488,7
6	4518,73	91131,9
7	4523,07	99422,6
8	4527,4	91322,6
9	4531,74	90434,8
10	4536,08	92760,1
11	4540,41	89760,5
12	4544,75	83601,3
13	4549,08	89554,2
14	4553,42	96188,9
15	4557,75	86803,4
16	4562,09	87639,6
17	4566,43	94463,4
18	4570,76	82310,6
19	4575,1	90455
20	4579,43	85650,6
21	4583,77	82716,3
22	4588,1	89565,4
23	4592,44	86260,4
24	4596,78	83570,2

Microsoft Excel - n4725_spr

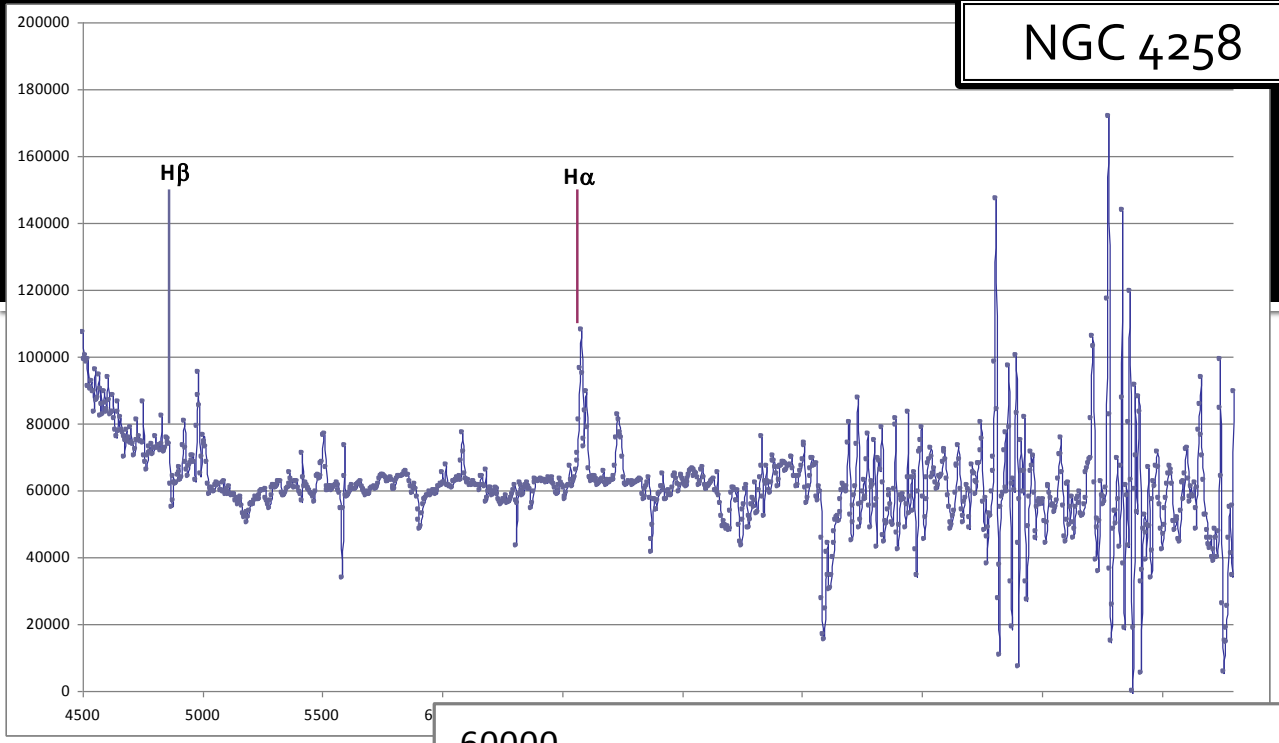
File Edit View Insert Form

Calibri 11 B

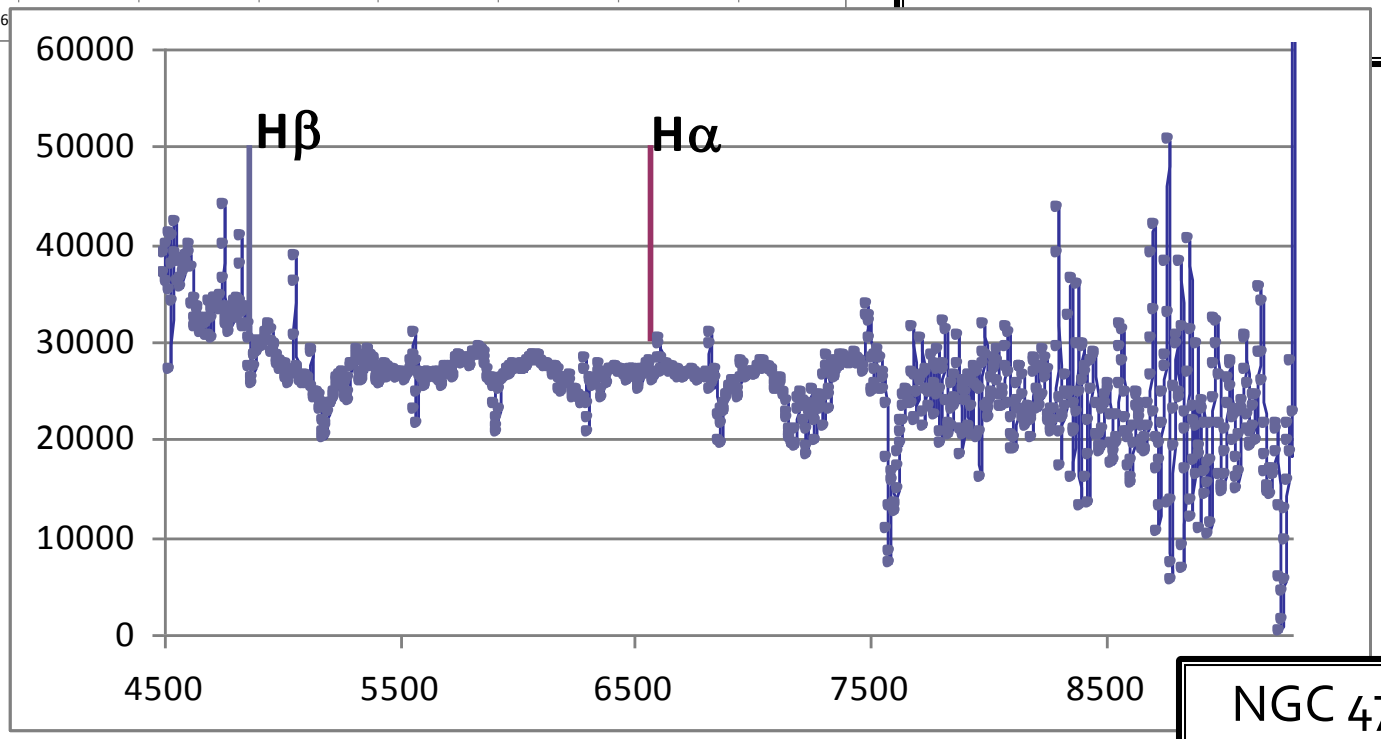
D7

	A	B	C
1	λ;10^{-10} m	spr	
2	4501,39	39011,9	
3	4505,72	36907,7	
4	4510,06	35989,9	
5	4514,4	39828,2	
6	4518,73	41067,7	
7	4523,07	35119,2	
8	4527,4	27104,9	
9	4531,74	33963,2	
10	4536,08	37871,6	
11	4540,41	40785,7	
12	4544,75	42229	
13	4549,08	39162	
14	4553,42	38061,2	
15	4557,75	38131,9	
16	4562,09	38350,5	
17	4566,43	36151,8	
18	4570,76	36493,8	
19	4575,1	35453	
20	4579,43	36887,9	
21	4583,77	38418	
22	4588,1	37909,7	
23	4592,44	37715,5	
24	4596,78	38300,2	

NGC 4258



Here are the relations between *intensity and wavelength.* Abscissa- wavelength; in angstroms. Ordinate- intensity; in notional values.

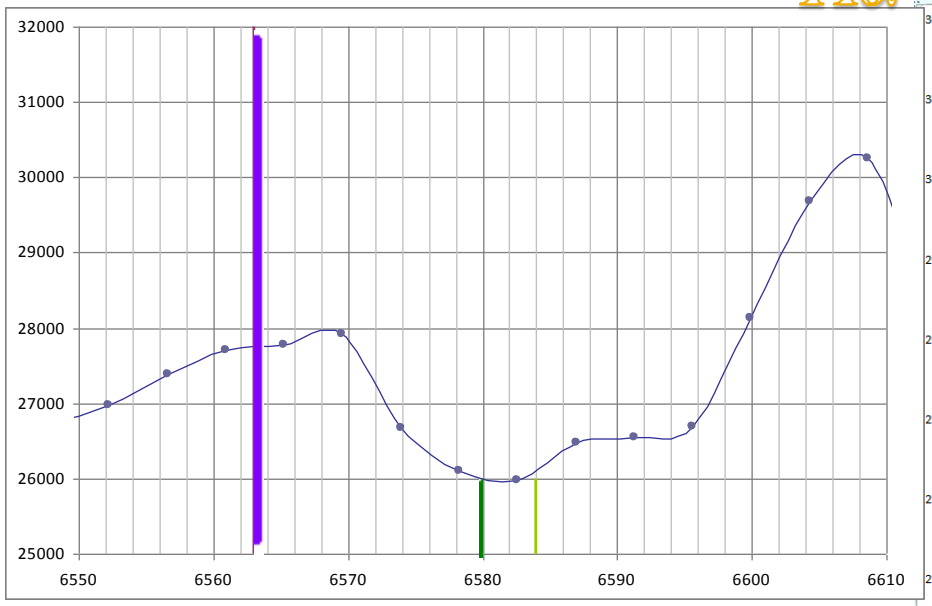


NGC 4725

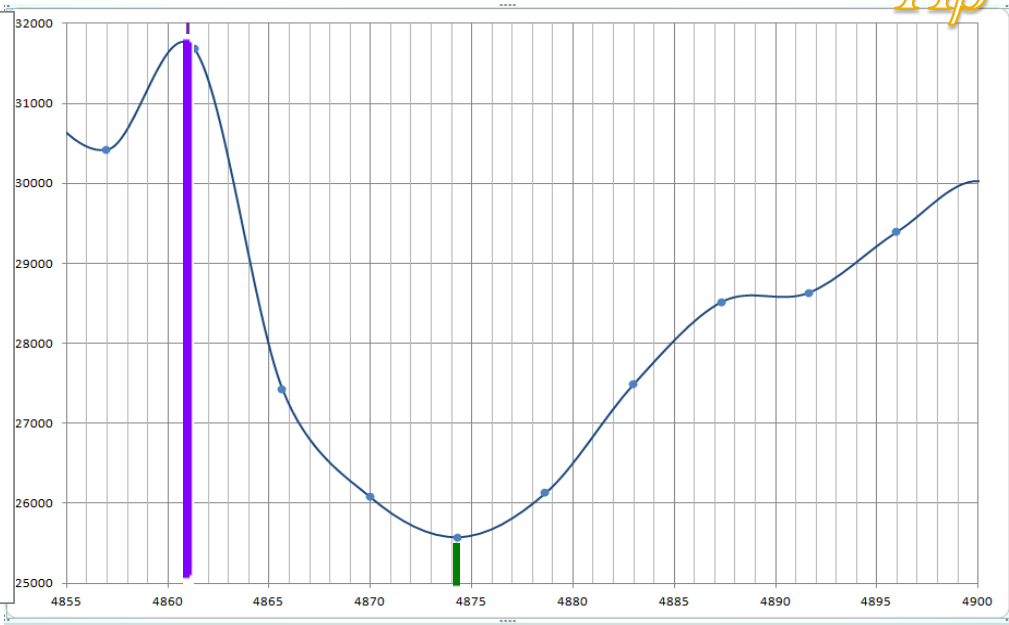
NGC4725

Below are shown the lines Hα and Hβ of hydrogen.
Purple lines show the location of Hα and Hβ if the source was at a halt.
Green lines represent the current location of the same lines in the NGC4725 spectrum.The distance between green and purple lines represents Redshift, $\Delta\lambda_\alpha$ and $\Delta\lambda_\beta$ for NGC4725.

Hα



Hβ

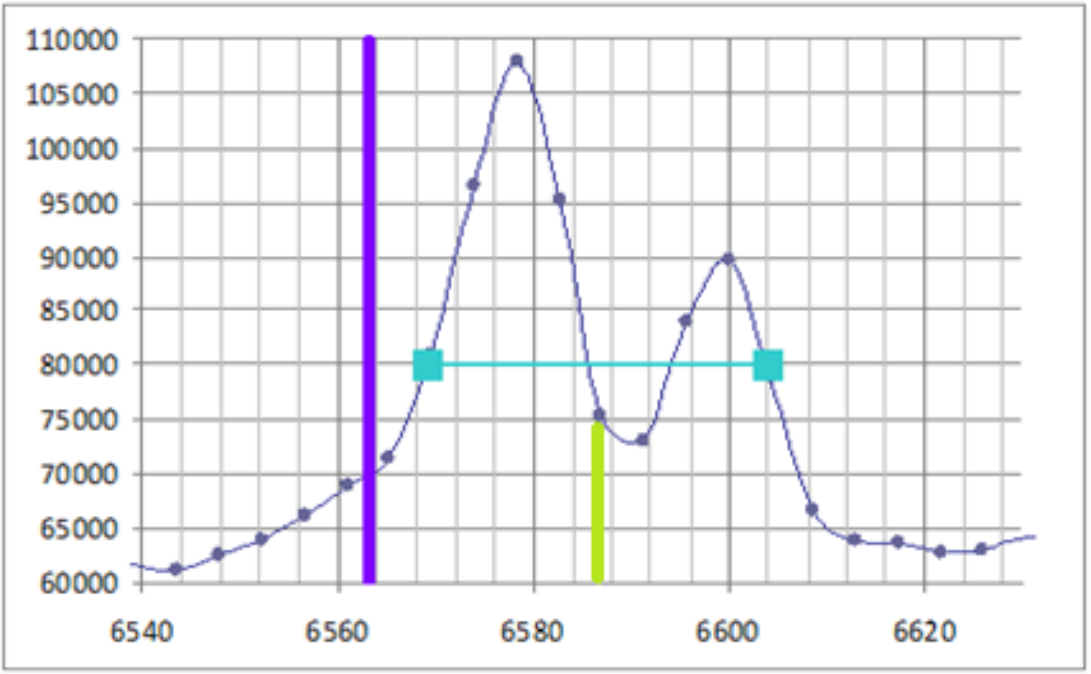


Using these graphs we measured Hα=6584 Å and Hβ=4874 Å

NGC4258

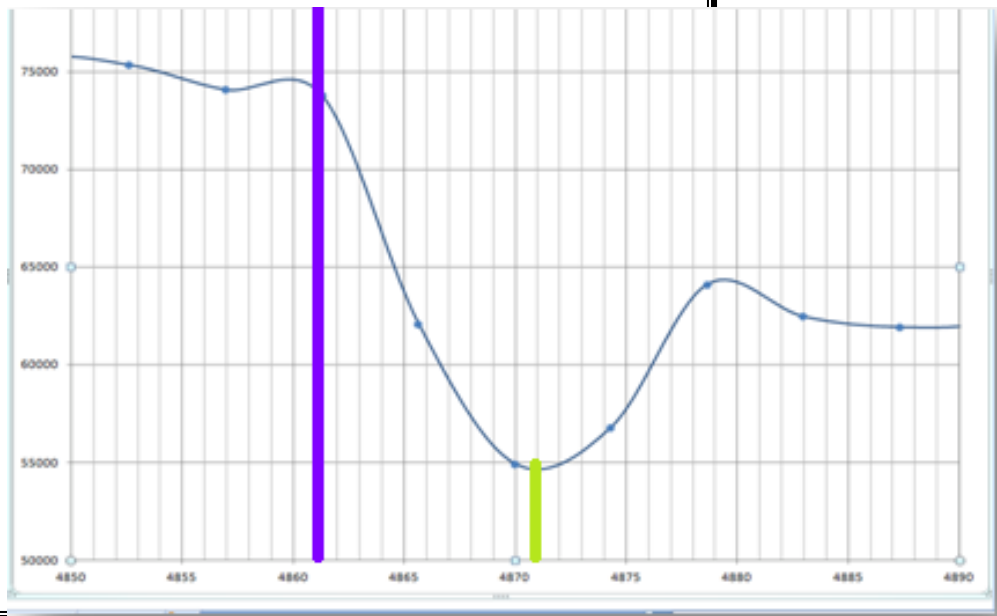
The same method is applied to NGC 4258.

Hα=6586 Å Hβ=4871 Å



The Balmer series is characterized by the electron transitioning from $n \geq 3$ to $n = 2$, where n refers to the radial quantum number or principal quantum number of the electron.

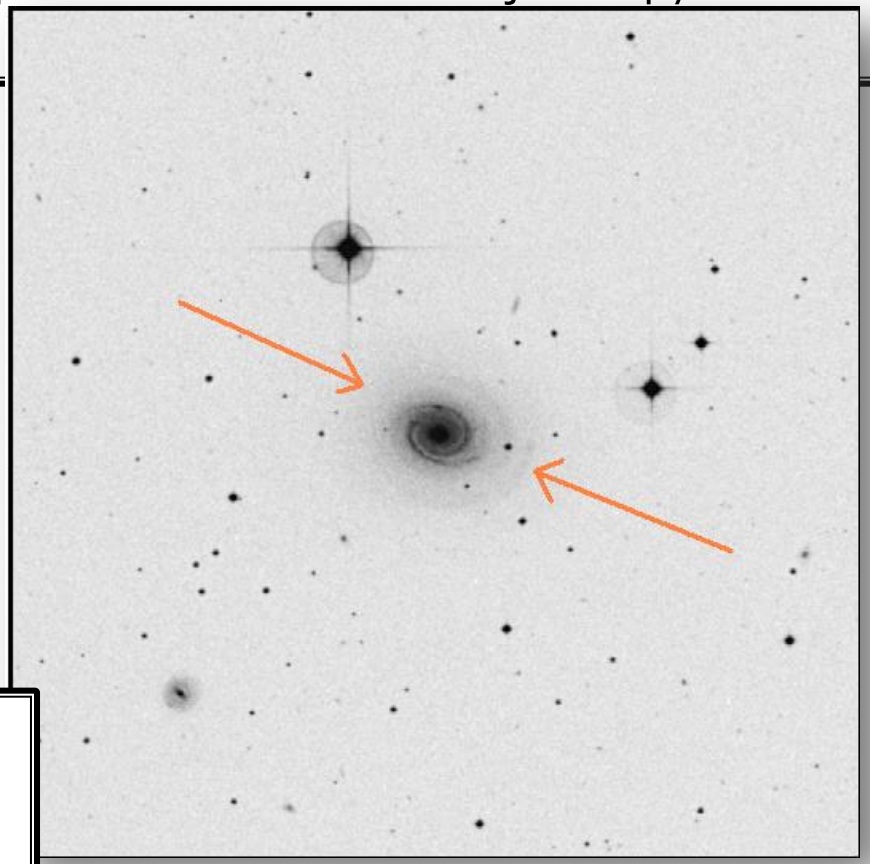
The transitions are named sequentially by Greek letter: $n = 3$ to $n = 2$ is called H-α, 4 to 2 is H-β.



An ambitious task such as defining the age of the Universe cannot be solved using data from two galaxies only. For that matter we need data from numerous galaxies. In the beginning we were planning to use information about the speed and distances to 20 other objects. In our research we stumbled upon this website:

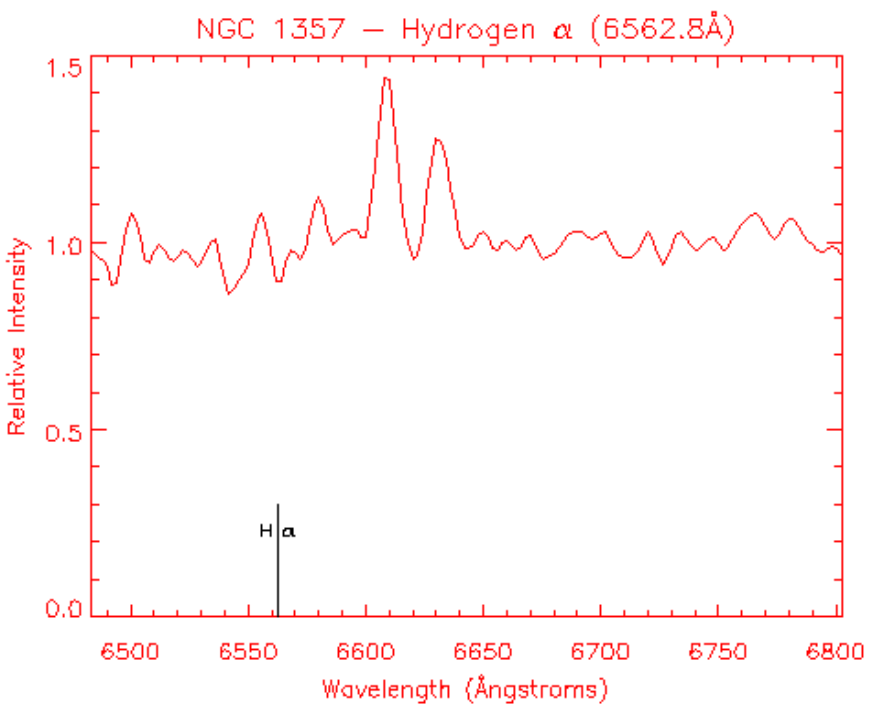
http://astro.wku.edu/astr106/HubbleLaw.html

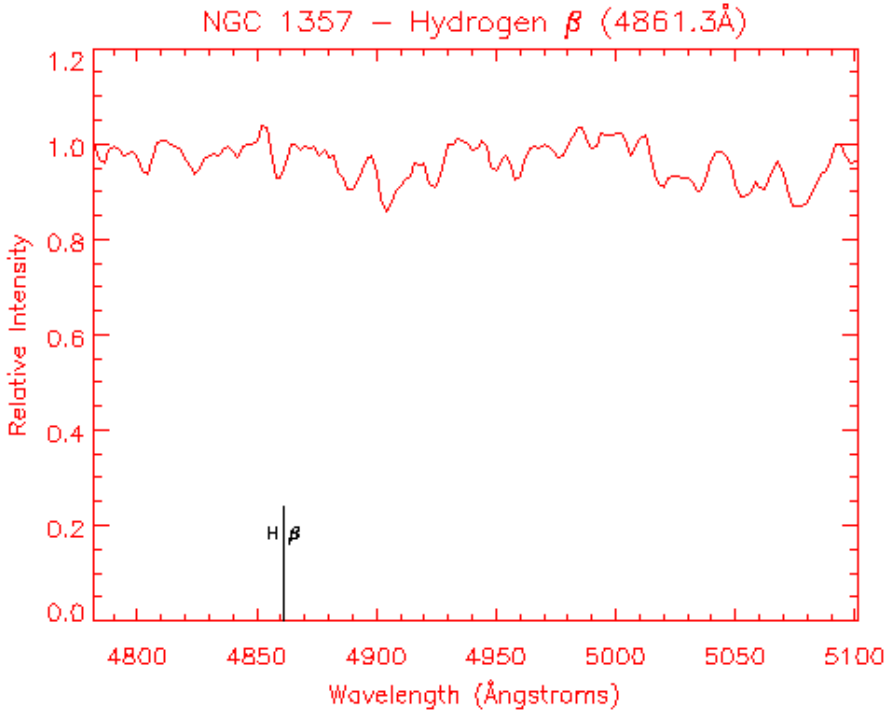
This website helped us measure the required values rather than just copy them. Here is how:



By clicking the edges of the diameter of the galaxy we get the angular size in milliradians.

Clicking the Hα or Hβ line in a spectrum, the software gives us a corresponding value.





We made an electronic table where we utilized formulae calculating Hubble's constant and the age of the Universe. We input angular sizes and wave lengths from the website as well as from our observation.

.

Results:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Galaxy	a-Angular size; mrad	Hα; Å	Hβ; Å	$z_\alpha=\Delta H_\alpha/H_\alpha$	$z_\beta=\Delta H_\beta/H_\beta$	d (Mpc) = s / a	z average	$v = c\,z$; km/s	H=v/d ;km/s.Mpc	$H*10^{-5}$; km*s/ly	t=1/H* 10^{18};s	$t; .10^9$ y	Δt_i; 10^9 y	Δt_i^2; 10^{18} y2
2	NGC 3034	2.72	6555.5	4857.4	-0.001	-0.001	8.09	-0.001	-286.99	-35.48	-10.88	-0.87	-28	rejected blue shift	
3	NGC1357	0.8	6597.7	4879.3	0.005	0.004	27.50	0.005	1352.14	49.17	15.08	0.63	-8	33	2537
4	NGC2276	0.65	6605.5	4890.2	0.007	0.006	33.85	0.006	1866.38	55.14	16.92	0.56	18	7	53
5	NGC2903	3.05	6566.5	4861.3	0.001	0.000	7.21	0.000	84.51	11.72	3.59	2.63	83	-58	3412
6	NGC3147	0.91	6611.7	4902.7	0.007	0.009	24.18	0.008	2393.42	99.00	30.37	0.31	10	15	229
7	NGC3368	2.47	6595.3	4866	0.005	0.001	8.91	0.003	887.22	99.61	30.56	0.31	10	15	231
8	NGC3627	2.08	6569.6	4863.7	0.001	0.000	10.58	0.001	229.32	21.68	6.65	1.42	45	-20	403
9	NGC 4775	0.52	6586.8	4877.7	0.004	0.003	42.31	0.004	1053.85	24.91	7.64	1.24	39	-14	203
10	NGC 5548	0.34	6662.5	4933.9	0.015	0.015	64.71	0.015	4515.73	69.79	21.41	0.44	14	11	121
11	NGC 6181	0.59	6600	4888.7	0.006	0.006	37.29	0.006	1694.51	45.44	13.94	0.68	22	3	12
12	NGC 6643	0.88	6584.4	4874.6	0.003	0.003	25.00	0.003	903.44	36.14	11.09	0.85	27	-2	4
13	NGC 3310	0.84	6571.1	4866.8	0.001	0.001	26.19	0.001	359.16	13.71	4.21	2.25	71	-46	2140
14	NGC 4631	3.59	6569.6	4860.6	0.001	0.000	6.13	0.000	133.73	21.82	6.69	1.41	45	-20	391
15	NGC 1832	0.7	6596.9	4885.5	0.005	0.005	31.43	0.005	1525.04	48.52	14.88	0.64	20	5	24
16	NGC 2775	1.16	6582.9	4882.4	0.003	0.004	18.97	0.004	1109.69	58.51	17.95	0.53	17	8	69
17	NGC 3227	1.13	6598.5	4882.4	0.005	0.004	19.47	0.005	1466.00	75.30	23.10	0.41	13	12	145
18	NGC 3623	2.3	6591.4	4864.5	0.004	0.001	9.57	0.003	751.90	78.61	24.11	0.39	12	13	158
19	NGC 3941	0.87	6593.8	4868.4	0.005	0.001	25.29	0.003	926.97	36.66	11.24	0.84	27	-2	3
20	NGC 5248	1.83	6576.6	4869.1	0.002	0.002	12.02	0.002	555.70	46.22	14.18	0.67	21	4	15
21	NGC 5866	1.67	6586	4865.2	0.004	0.001	13.17	0.002	650.14	49.35	15.14	0.62	20	5	27
22	NGC 6217	0.76	6580.5	4873	0.003	0.002	28.95	0.003	765.03	26.43	8.11	1.17	37	-12	143
23	NGC 6764	0.63	6600.8	4885.5	0.006	0.005	34.92	0.005	1614.11	46.22	14.18	0.67	21	4	15
24	NGC 7469	0.56	6650	4920.7	0.013	0.012	39.29	0.013	3823.22	97.32	29.85	0.32	10	15	224
25	NGC4725	our observation	6584	4874	0.003	0.0026	12.27	0.003	875.81	71.38	21.90	0.43	14	11	128
26	NGC4258	our observation	6586	4871	0.004	0.0020	6.9	0.003	828.98	120.14	36.85	0.26	8	17	284
27			t aver=	25	$.10^9$ years		Δt_{sqr}=	4	$.10^9$ years		$t_{universe}$= (25±4) $.10^9$ years				

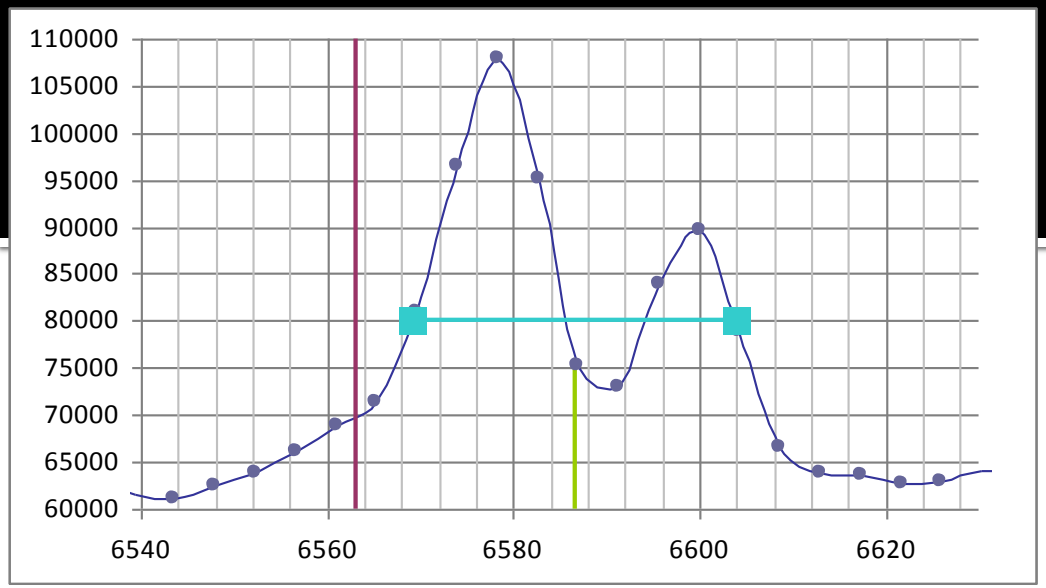
Sheet1 Sheet2 Sheet3

Some explanations of the columns of the table:

- d (Mpc) = s (kpc) / a (mrad),
- is the distance to the galaxy . We assume that all of these galaxies are about the same size. From other methods we know that galaxies of the type used in this project are about **s = 22 kpc.**
- 1 pc = 3,26 ly
- We turned the units of Hubble's constant, **H**, from **km/s.Mpc** to **10^{-6} km/s.ly** because these units are used in Bulgarian textbooks
- **t** = (9,46.10^{12} km/ly)/ H km/s.ly is the age of the Universe in seconds – column **L**
- **t** in column M is the age of the Universe in billion years.
- The last two columns were made for calculations of the root mean square error.

Analysis of the results

1. Taking a closer view of the particular galaxies in our research for quite a small part of them the values got for the age of the Universe coincide with the generally acknowledged. That refers to the observed galaxy NGC 4258. / For NGC 4725, the number we got for the age of the Universe is 14 billion years. It is perfectly the same like the data from 2013 (13,77 billion years) / For NGC 4258, the number we got is nearly twice lower. We searched for the reasons for the incongruity.



We checked if the spectrum has been properly built..
After the comparison of the three spectra it is noticed that the peeks of their lines represent the same wave lengths in each of the graphics /from our observation, the authors of the article[6] and the archive graphic used by them/. That leads to the conclusion that there is no mistake in the spectrum built by us.

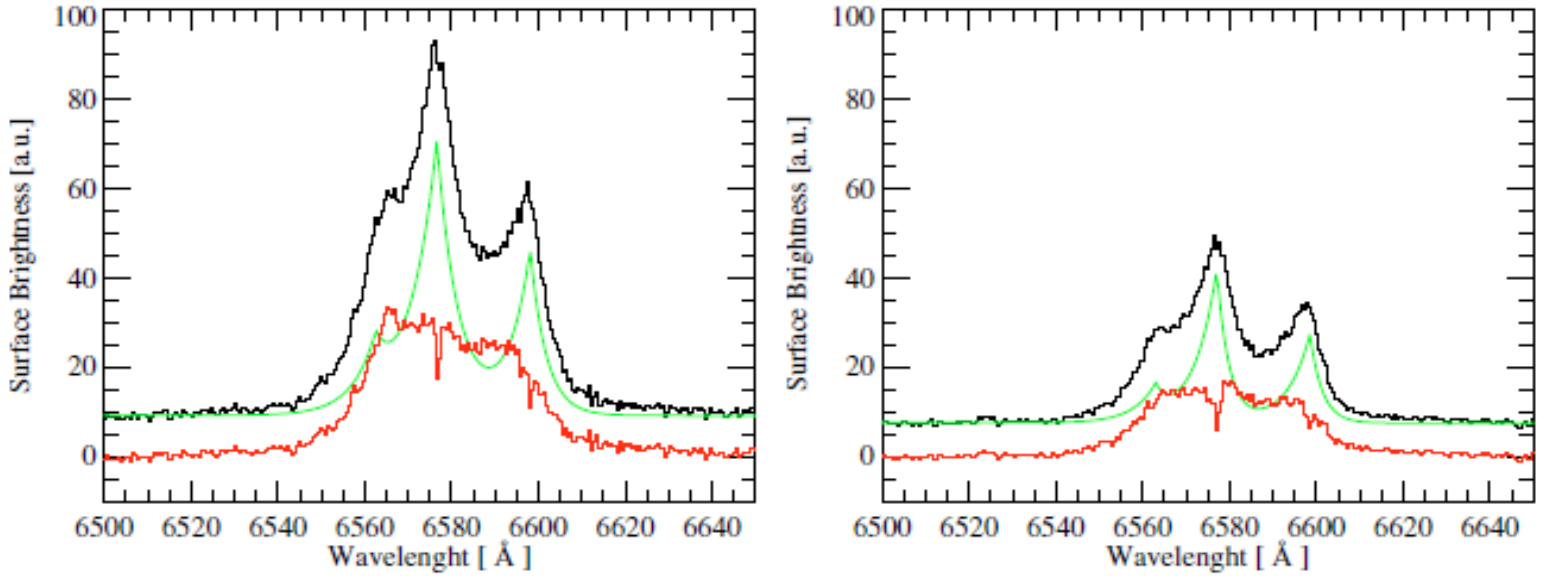


Fig. 5. The black line shows the observed NGC 4258 nuclear spectrum, the green one the narrow lines used for subtraction; the residuals are drawn in red. These residuals represent the Broad Hα Line. The left and the right panels refer, respectively, to archival and our own data.

Another explanation for the dispersion of the results we found:

http://www.astro.cornell.edu/academics/courses/astro201/hubbles_law.htm

The expanding of the Universe is not the only motion in which the galaxies take part in. Frequently to the velocity enlargement is considered to occur either addition or deduction in the individual motion of each galaxy. It may be due to the fact that the cloud, formed by the galaxies, has its own velocity. The velocity of this particular motion is not that high. That causes the low diversions from the age of the Universe.

We assume that the diversion in the results for NGC 4258 is due to the reasons stated above.

•*Significantly higher are the rates for the velocity of the galaxy clusters around their gravity center. The mass of those clusters is immense and their orbital speed may exceed 1000 km/s. They are the reason for the big digression from the age of the Universe.*

•***Most probably that is the exact reason for the digression for NGC 2903, 3310, 3627, 4775*** .

2. The average number for the age of the Universe / 25±4 billion years / is close to the generally accepted one /13,73±0,12 billion years, based on observations of the cosmic microwave background (CMB) radiation, according to the WMAP data from 2013**/. It is higher than the age of the oldest star /13.2 billion years/**. That comparison is one of the ways to verify our calculations. We assume that they are quite acceptable for high-school students.

Conclusion

The purpose of this project is educational, not scientific. It gives us a general perception of methods and phases in scientific researches. Our contribution is:

- We used data from researching the NGC4725 and NGC4258 galaxies.
- Processed results in an electronic table, that we made.
- Used a statistic method, not graphical, for determining Hubble's constant and the age of the Universe. This gave us more realistic results.

The theory we used is available for students in middle schools.

We reckon that a practical activity such as determining the age of the Universe would be a challenge for students in general as it was for us.

Sources:

1. http://www.nao-rozhen.org
2. *http://bg.wikipedia.org/wiki*
3. http://www.starrydreams.com
4. www.spacetelescope.org
5. **Magazine "Znanie"; N40, april 2013**
6. **G. Pastorini and others,Supermassive black holes in the Sbc spiral galaxies NGC 3310, NGC 4303 and NGC 4258, Astronomy& Astrophysics**
7. http://helixgate.net/ngc4725.html
8. http://www.astro.cornell.edu/academics/courses/astro201/hubbles_law.htm

We gratefully acknowledge observing grant support from the Institute of Astronomy and Rozhen National Astronomical Observatory, Bulgarian Academy of Sciences.

Made by
Denitsa Baleva,
Annie Vasileva
and Gratsiela Ilieva
leader of the group: Aneta Marinova