

Photometric redshifts of the galaxies near the X-ray source 2MASX J14391186+1415215

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ABSTRACT

The aim of this work is to measure the distance of some galaxies belonging to what appears to be a small group, and so to determine which ones are only prospectively aligned. The distance was obtained by Hubble's law and the recession velocity of the galaxies, by comparing their broadband ugriz photometric data to rest-frame template spectra of galaxies with different morphology.

I. INTRODUCTION

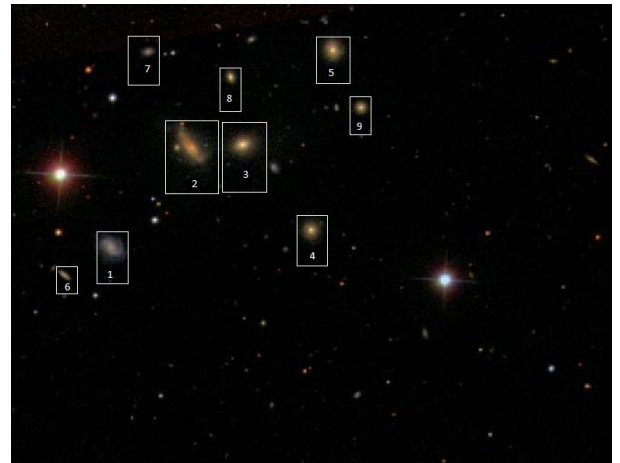
The recession of the galaxies is a common phenomenon of every zone of the sky. It is a motion that, keeping the same characteristics, could be seen from any part of the Universe.

An empirical observation leads to fix a directly proportional dependence between the recession velocity of the galaxy and its own distance. This experimental law is called Hubble's law. In order to determine the recession velocity, the spectral shift expected by Doppler's effect is exploited: the apparent frequency of an electromagnetic wave, emitted by a source moving relatively to the observer, changes from the measured frequency of the source at rest, depending on the velocity. In particular, if the source and the observer are approaching to one another an apparent increase of the frequency is noticed, vice versa a decrease is noticed. Being the galaxies all receding the spectrum appears shifted towards lower frequencies. This phenomenon is called *redshift*.

II. OBSERVATIONAL DATA

The data were extracted from the public archive of the Sloan Digital Sky Survey (SDSS). They consist of images of the same field around the X-ray source 2MASX J14391186+1415215 obtained with broadband filters *u*, *g*, *r*, *i*, *z*, which cover the spectral regions from near-ultraviolet to near-infrared. Nine objects were selected having been certainly identified as galaxies.

The considered galaxies are highlighted in the following figure. A number is associated to each of them in order to easily identify them.



III. WORK DESCRIPTION

First of all we need to reconstruct the spectrum of the observed galaxies. This is done by means of a photometric analysis, which allows us to determine a flux value for each galaxy in each broadband filter (*ugriz*). We applied the software SExtractor (Source-Extractor) to our images, which is a program that builds a catalogue of objects for each analyzed frame. This program identified the galaxies, by using the parameters we had previously set, and calculated the

counts detected for each source, subtracting the sky contribution.

Galaxy	u (3551 Å)	g (4686 Å)	r (6165 Å)	i (7841 Å)	z (8931 Å)
1	1456.0	47308.0	57841.9	63956.2	11590.4
2	1222.3	50396.1	108338.0	144327.0	33052.2
3	2746.2	61701.9	112801.0	142925.0	30159.0
4	1042.5	28606.7	54781.3	72735.7	15901.1
5	1985.0	45274.4	81062.4	102823.0	23172.9
6	251.3	6288.8	11020.5	14164.5	3420.9
7	140.4	6775.1	9873.0	10791.6	1771.0
8	661.7	15086.9	27824.3	33527.8	7641.5
9	689.2	17178.1	31206.1	39987.8	9175.9

The so-obtained flux is still in photon counts and has to be converted in magnitudes. Therefore, if the instrumental magnitude of the target per time unit is given by the formula:

$$m_t = -2.5 \log \left(\frac{E}{t_{\text{exp}}} \right)$$

being E the collected energy and t_{exp} the exposure time, then, the real apparent magnitude of the target, called m , is :

$$m = m_0 + m_t - kx$$

where m_0 is a constant named *photometric zero point* which depends on the filter used, while the kx product is the correction term for atmospheric extinction, which depends on the *extinction coefficient* k , and on the *airmass* x , that is a function of the target altitude above the horizon (h), precisely:

$$x = \frac{1}{\sin h}$$

Considering together the two equations containing magnitudes we have:

$$m = m_0 - 2.5 \log \left(\frac{E}{t_{\text{exp}}} \right) - kx$$

From Pogson's formula, we know that:

$$m = -2.5 \log \left(\frac{f}{f_0} \right)$$

being f the flux and f_0 the referring flux of the photometric system. Therefore, by rearranging the last two equations, we obtain:

$$\frac{f}{f_0} = \frac{E}{t_{\text{exp}}} 10^{0.4(kx - m_0)}$$

From the SDSS website we know that the flux, in Jansky units, is given by the following formula:

Galaxy	Magnitudes				
	u (3551 Å)	g (4686 Å)	r (6165 Å)	i (7841 Å)	z (8931 Å)
1	19.59	16.85	16.31	15.93	15.92
2	19.78	14.28	15.63	15.05	14.78
3	18.90	16.56	15.59	15.06	14.88
4	21.06	18.87	17.79	17.18	16.76
5	19.25	16.90	15.94	15.42	15.17
6	21.49	19.04	18.11	17.57	17.24
7	22.13	18.96	18.23	17.86	17.96
8	20.44	18.09	17.11	16.63	16.37
9	20.40	17.95	16.98	16.44	16.17

$$s = 3631 \frac{f}{f_0} \quad \text{Jy}$$

As a consequence:

$$s = 3631 \frac{E}{t_{\text{exp}}} 10^{0.4(kx - m_0)} \quad \text{Jy}$$

But Jansky are expressed in frequency units (1 Jansky = $10^{-23} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ Hz}^{-1}$) instead of wavelength units ($\text{erg cm}^{-2} \text{ s}^{-1} \text{ Å}^{-1}$), so we had to multiply by c/λ^2 and we obtained:

$$s = 3631 \frac{c}{\lambda^2} \frac{E}{t_{\text{exp}}} 10^{0.4(kx - m_0)}$$

Using this formula we calculated the flux values for each galaxy in each filter (characterized by a central wavelength) and we were able to trace a spectrum profile based on 5 points.

Galaxy	Computed flux (in $10^{-16} \text{ erg cm}^{-2} \text{ s}^{-1}$)				
	u (3551 Å)	g (4686 Å)	r (6165 Å)	i (7841 Å)	z (8931 Å)
1	1.26	9.04	8.57	8.24	5.85
2	1.06	516.60	257.85	648.13	1180.80
3	2.41	64.72	273.93	663.01	1139.50
4	0.32	1.41	2.18	2.62	2.71
5	1.72	8.65	12.00	13.25	11.70
6	0.22	1.20	1.63	1.83	1.73
7	0.12	1.29	1.46	1.39	0.89
8	0.57	2.88	4.12	4.32	3.86
9	0.60	3.28	4.62	5.15	4.63

Comparing our spectra with the ones of galaxies at a redshift $z=0$ we determined the galaxy's redshift, the receding velocity, and then the distance using Hubble's law. The redshift is expressed by the formula:

$$z = \frac{\lambda - \lambda_0}{\lambda_0}$$

where λ is the observed wavelength of a spectral line, λ_0 is the same at rest.

The Doppler effect is expressed by:

$$\lambda = \lambda_0 \sqrt{\frac{1 + \frac{v}{c}}{1 - \frac{v}{c}}}$$

where v is the receding velocity.
We have therefore:

$$v = c \frac{(1+z)^2 + 1}{(1+z)^2 - 1}$$

Finally, being by Hubble's law $v = H d$

$$d = \frac{c}{H} \frac{(1+z)^2 + 1}{(1+z)^2 - 1}$$

IV. RESULTS

First of all, by analyzing the results, we found an unexpected problem: due to the small number of photometric data, the spectrum shape was uncertain, and as a consequence the galaxy's morphology was also uncertain. This is also caused by the photometric redshift method being not very precise, especially when not used with an adequate software. For these reasons some spectra were attributed, in some cases, to two different types of galaxies which correspond to highly discordant redshifts. For example, the spectrum of the galaxy n. 4 was fitted with that of a Seyfert 2, confirmed after a comparison with literature, at redshift 0.5 and distance of about 1600 Mpc. But for galaxy number 9, we obtained two different redshifts and distances, 2250 Mpc and 470 Mpc. We chose the first one taking into account that this galaxy appeared much smaller than galaxy 4, and therefore we hypothesized that it was more distant. In other cases we were unable to decide between the two options, both being reliable. For example, the galaxy number 1 in both cases resulted to have a Sc morphology, with redshift 0.5 and therefore distance of 1600 Mpc, or redshift 0.8 and consequently distance 2200 Mpc.

To summarize, we can say that the distances found let suggest that these galaxies form a group. Nevertheless, we are not able to confirm it, because of the uncertainties of the applied method.

Galaxy	Type	z	V (km/s)	D (Mpc)
1	Sc	0.5	115305	1600
2	Sc	0.79	157173	2180
3	E	0.72	148321	2060
4	Sy2	0.5	115305	1600
5	Sa	0.22	58840	820
6	Sc	0.8	158381	2200
7	Sc	0.78	155952	2165
8	Sc	0.8	158381	2200
9	Sc	0.83	161922	2250

