Galaxy redshift and velocity measurements using the Lhires III spectrograph

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Abstract

The capability for the Shelyak Lhires III spectrograph mounted to a 0.35m telescope under suburban skies to measure galactic distances is tested. Results show that for bright galaxies, the instrument is capable of producing results that allow redshift and velocity determination comparable to published, peer reviewed results.

Figure 1: The spiral galaxy M83 *(image credit: Paul Luckas)*

1 Hardware and software

This test utilises high-end small telescope instrumentation under light polluted, suburban skies with typical stellar profiles exhibiting a FWHM of between 2 - 4 arc seconds. The Shelyak Lhires III spectrograph is mounted to a *DeepSkyInstruments* 0.35m RC f/7 telescope at the nominal back focus distance of 213mm. Guiding is accomplished using an off-axis guider coupled to the image train of the main instrument, while target positioning on the slit is facilitated using a live video feed through the guider port of the Lhires III spectrograph.

Device control and automation is accomplished using a combination of proprietary and ASCOM [1] control software. Telescope mount control is provided using *TheSkyX* [5], which also provides autoguider control and a target view via the built-in camera and video modules of the software. Control of the RC14's ASCOM-enabled focuser is also undertaken using *TheSkyX*, though the composite structure of the RC14C's optical tube mitigates the need for periodic re-focus of the telescope's secondary.

Spectral image acquisition is undertaken using *MaxIM DL* [3] which also provides for calibration frame (dark, bias, flat field) acquisition. The sequencing of long integrations (typcially n x 600 second exposures) together with before/after neon calibration frames is accomplished using CCD Commander [7]. The Lhires III includes a motorised calibration and flat lamp assembly which has been interfaced to the observatory PC for scripted operation, and in this way can be controlled automatically as part of an imaging run.

Spectrum details:

Date	Exposure	R	SNR
19th April, 2016	6 x 600s	15,000 @ 6532Å	< 20

1. Redshift. The redshift determined using the difference between the measured and rest wavelength for Hα:

$$z \equiv \frac{\lambda - \lambda_0}{\lambda_0} = \frac{\Delta\lambda}{\lambda_0} = 0.001644 \quad (1)$$

2. Radial Velocity. A heliocentric radial velocity of 493 km/s was determined using the standard optical approximation (redshifts z<0.1):

$$v = c\frac{\Delta\lambda}{\lambda} \quad (2)$$

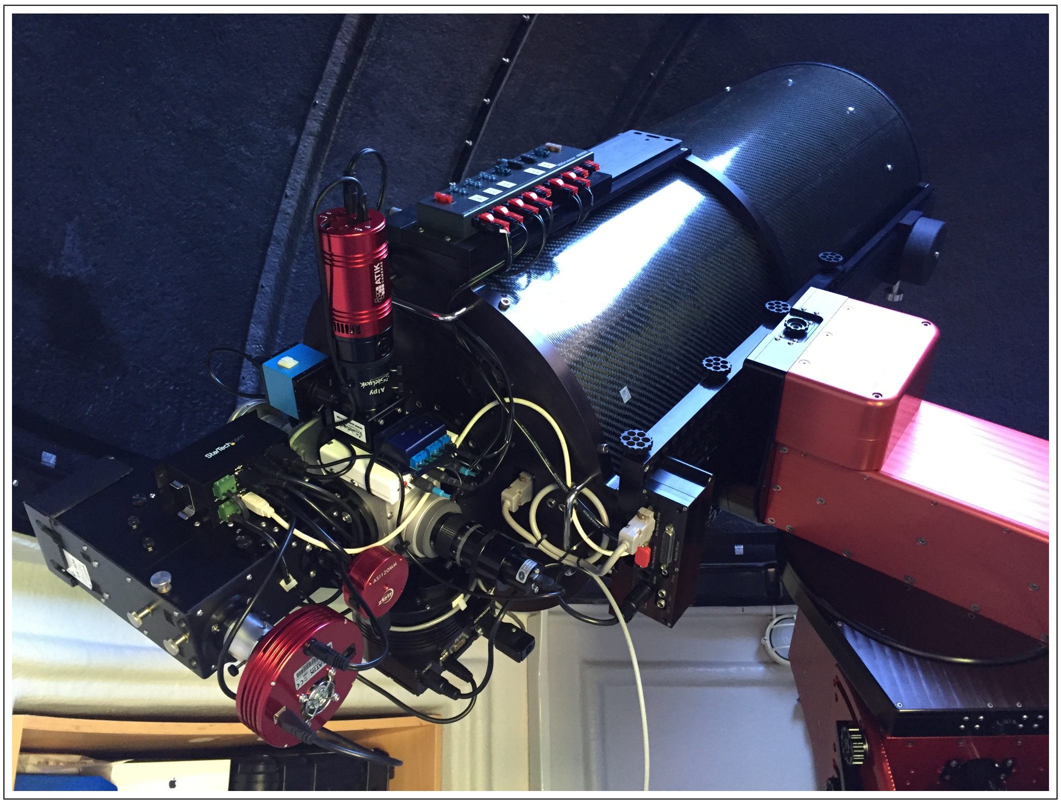

Figure 2: The RC14C telescope. The image train includes a Lhires III spectrograph (rear most instrument), a low resolution spectrograph (3 o'clock position), and a photometric CCD camera (barely visible at 9 o'clock position). An optical manifold allows manual selection of the preferred instrument package.

for the maximum flux value of 6573.5Å measured across a selcted width of 7.3Å on the prominent Hα feature. This compares well with the published value on most recent papers of around 513 km/s.

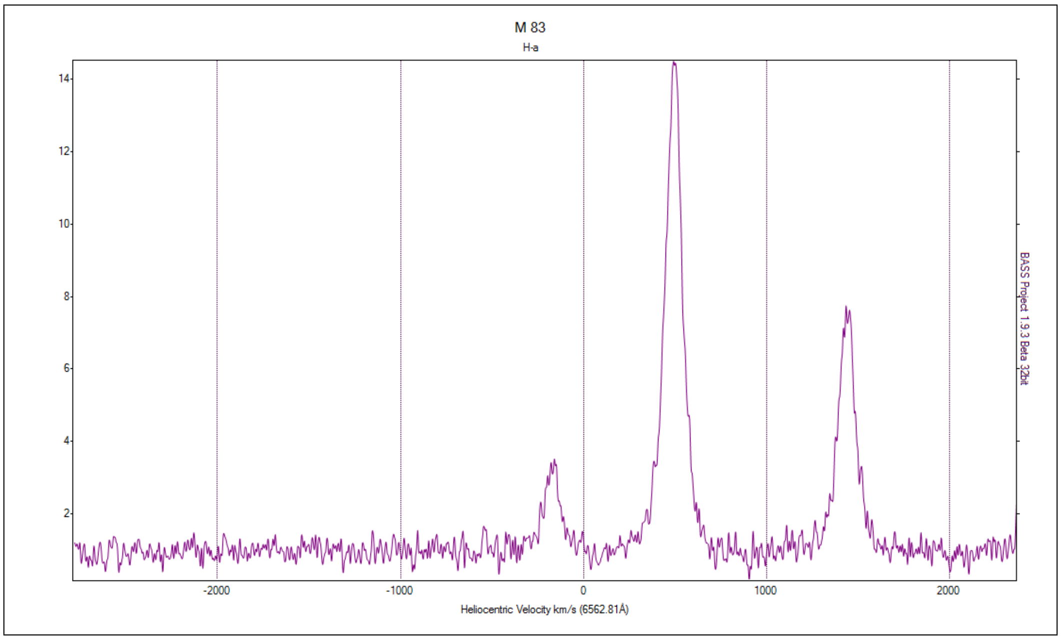

Figure 3: Calibrated spectrum

In fact, the result is closer to published values of mid to late last century, perhaps reflecting the crude point and click single-line measurement of the Hα feature which is known to include components of N II.

No.	Frequency Targeted	km/s +/- unc		z +/- unc		Reference Code
0		513	2	0.001711	0.000007	2004AJ....128...16K
1		513	2	0.001711	0.000007	2004AJ....128...16K
2		513	2	0.001711	0.000007	2014MNRAS.440..696A
3		515	3	0.001718	0.000010	2003MNRAS.339..652K
4	21-cm HI line	516	4	0.001721	0.000013	1991RC3.9.C...0000d
5	21-cm	514	5	0.001713	0.000017	2006HIPAS.C...0000:
6	Optical lines	503	11	0.001678	0.000037	1991RC3.9.C...0000d
7	Optical	497	18	0.001658	0.000060	1992CORV..C...0000F
8	Optical	445	20	0.001484	0.000067	1992CORV..C...0000F
9	Optical	488	27	0.001628	0.000090	1992AJ....103...11F
10	Optical	491	30	0.001638	0.000100	1956AJ.....61...97H
11	Optical	500	50	0.001668	0.000167	1992CORV..C...0000F
12	Optical	330		0.001101		1992CORV..C...0000F
13	Optical	418		0.001394		1992CORV..C...0000F
14	Optical	480		0.001601		1992CORV..C...0000F
15	Optical	504		0.001681		1992CORV..C...0000F
16		508		0.001695		2013AJ....146...86T
17	Optical	509		0.001698		1992CORV..C...0000F
18		513		0.001711		2012A&A...544A..18V
19	Optical	516		0.001721		1992CORV..C...0000F
20	Optical	516		0.001721		1992CORV..C...0000F
21		518		0.001728		2013ApJ...766..108M
22		518		0.001728		2013ApJ...779...33M
23		519		0.001731		2013AJ....145..101K

Figure 4: Historical velocity and redshift data for M83 extracted from NED

3. Distance. The distance to M83 can be recovered using Hubbles law:

$$d = \frac{cz}{H_0} = 7.04\text{Mpc} \tag{3}$$

(using current value of $H \sim 70$km/s/Mpc)

Though seemingly close to the mean published value in NED[1] of 6.5 Mpc, the difference is notable, particularly when converted to light years (22 million light-years compared to 15 million light-years).

References

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[5] Software Bisque. Software Bisque Home Page. Retrieved March 24, 2016, from http://www.bisque.com.

[6] O Thizy and F Cochard. Spectrographs for small telescopes. *International Astronomical Union. Proceedings of the International Astronomical Union*, 6(S272):282, 2010.

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[1] NASA/IPAC Extragalactic Database (http://ned.ipac.caltech.edu)