Two Volume-phased Holographic Grisms Now Available for EFOSC2

Ivo Saviane, Lorenzo Monaco (ESO)

Starting from Period 81, two new volume-phased holographic grisms are available to be used with EFOSC2. Testing of the grisms is described. Some results on measurement of the stellar Lithium doublet and galaxy rotation curves demonstrate the performance of the new grisms.

Two volume-phased holographic grisms (VPHG) were procured by the ULTRASPEC project (see Dihllon et al., 2007), and were first used in January–February 2008 for some of the science runs. Afterwards, the VPHGs were tested for scientific performance, and on the basis of the overall positive evaluation, it was decided to offer them to the community. Here we report on some of the tests that were performed on 13 and 14 February 2008. At that time the instrument was installed at the 3.6-m telescope; during the commissioning of EFOSC2 at the NTT (April 2008) the tests were repeated to assess the performance at the new focal station. The basic parameters of the two grisms are summarised in Table 1.

Basic characteristics

To characterise the grisms the usual set of calibration frames were taken: bias frames, one arc frame, and dome flat-field frames. In both cases, it was soon evident that part of the CCD is not illuminated because, after passing through the VPHG, the beam suffers a deviation in the spatial direction. Only ~ 70 % of the field of view is available when using the red VPHG, and ~ 65 % when using the blue grism. In terms of pixels, the useful area is 2021 × 1411 px for the blue grism, and 2021 × 1231 px for the red grism. Some reflections are also visible in the arc frame of the red grism, caused by the Helium lamp. It is thus suggested to have very short exposure times for this lamp, of the order of 0.1 sec. Redder than ~ 7000 Å fringes are visible in the flat-field frames of the red grism.

Arc lamp exposures were used to measure the dispersions and resolutions, which are listed in Table 1. Note that at the extremes of the spectral range the resolutions are degraded by ~ 50 % for the blue grism and ~ 30 % for the red grism. The highest dispersion of the current EFOSC2 grisms is 1 Å/px, so the blue and red VPH grisms offer values three and two times larger than what is currently available, respectively. Plots of the wavelength calibrated arcs are shown in Figure 1.

The two technical nights at the 3.6-m telescope were not photometric, so system efficiencies were obtained later with EFOSC2 at the NTT. They are shown in Figure 2, together with the efficiencies of the other grisms. The efficiency of the blue VPHG goes from 30 % at the red end, down to 20 % at the blue end. The red VPHG has a more constant response, with an efficiency around 30 %. In general, as Figure 2 shows, the system efficiencies are comparable to those obtained with the existing EFOSC2 grisms.

In order to determine whether the grisms are useful to obtain valuable science data, we took spectra to measure stellar abundances and to study the kinematics of spiral galaxies.

Measurement of Lithium line 6707.8 Å

Lithium is a fragile element which is easily destroyed in stellar interiors at relatively low temperatures. As a star approaches the giant phase, the deepening of the convective envelope brings to the star surface material which was depleted in Li in the stellar interior. Such mixing of Li-depleted and unprocessed material causes an overall dilution of the Li abundance at the star surface. Assuming that a star is born with a meteoric Li abundance (ALi ~ 3 dex), standard models predict that in giants the Li abundance should not exceed ~ 1.5 dex. Yet, about 1–2 % of K giants have Li abundances exceeding this value. A few of them even have a Li abundance similar or larger than the meteoric value.

The occurrence of Li-rich stars is usually explained in terms of a Li-production mechanism (Cameron & Fowler, 1971) in the stellar interior associated with a circulation mechanism to bring the produced Li to the star surface. However, a complete theory capable of explaining all the observational facts is still missing and particularly puzzling is the case of low-mass stars (e.g., Charbonnel & Balachandran, 2000; Uttenthaler et al., 2007).

For this reason, in parallel with improving models, data are being collected to construct a more complete observational picture. The Li abundance is routinely measured using the doublet at 6707.8 Å. To test the feasibility of such a measurement, we took spectra of three stars with different equivalent width (EW) of the Li doublet. The extracted and continuum-normalised spectra are shown in Figure 3, with signal-to-noise ratios better than 50. Clearly EWs of the Li line down to 300 mÅ can be easily measured, while the star with a 200 mÅ line is more ambiguous, because of its late spectral type. The doublet is probably detected, but a confirmation with an earlier type star is needed.

Rotation curves of spiral galaxies

Rotation curves of spiral galaxies are used to study their kinematics, in the search for the amount and distribution of dark matter (DM), which are constrained by departures from the expected velocity curve of a rotating disc. The rotation

Grism	Lines/mm	λmin	λcen	λmax	RS	nm/px	FWHM	Binning	Slit
#19/475	1557	444	478	511	3200[1]	0.034	0.15	1	0.5″
					3200	0.067	0.15	2	0.5″
					2200	0.067	0.21	2	1.0″
#20/656	1070	605	660	714	3400	0.055	0.20	1	0.5″
					3000	0.108	0.22	2	0.5″
					2000	0.109	0.33	2	1.0″

Table 1. Parameters of VPHGs provided by the ULTRASPEC team. Wavelengths are measured in nm.

[1] A resolution greater than 4000 is found by Vik Dhillon with Ultraspec; investigations are ongoing to see whether EFOSC2 can match this performance.

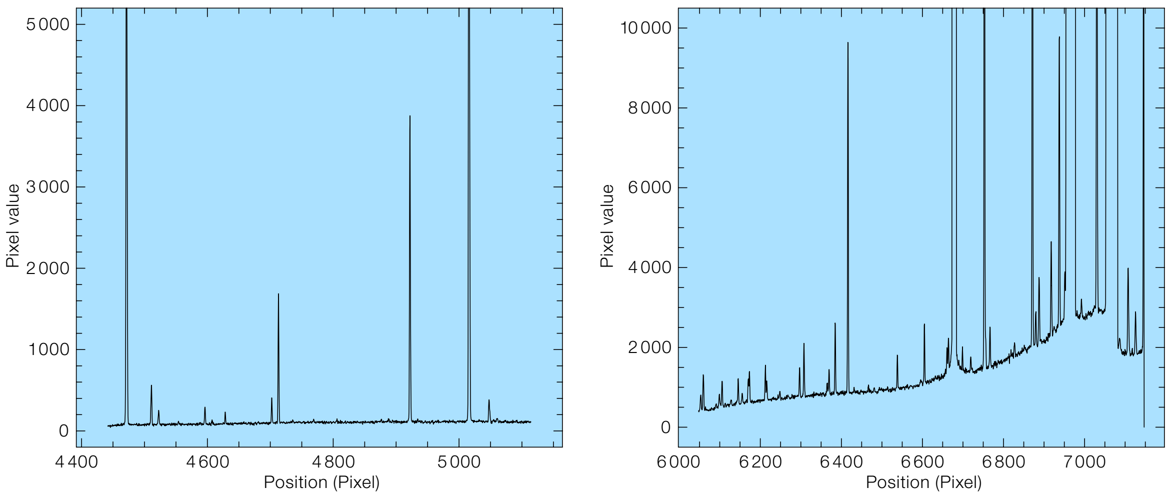

Figure 1. Wavelength-calibrated spectra of the Helium + Argon arc lamps taken with the blue VPH grism (left) and the red VPH grism (right). The high background in the red arc can be reduced by decreasing the exposure time of the He lamp.

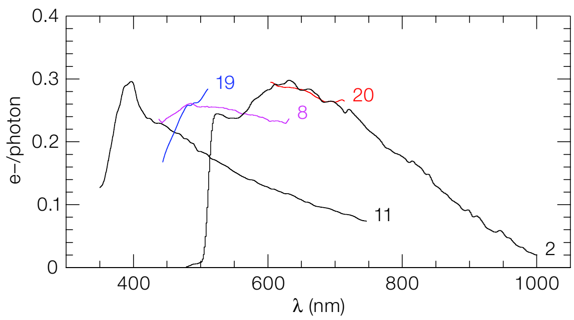

Figure 2. System efficiency given by the blue VPHG #19 (blue curve) and the red VPHG #20 (red curve) compared to that of other EFOSC2 grisms.

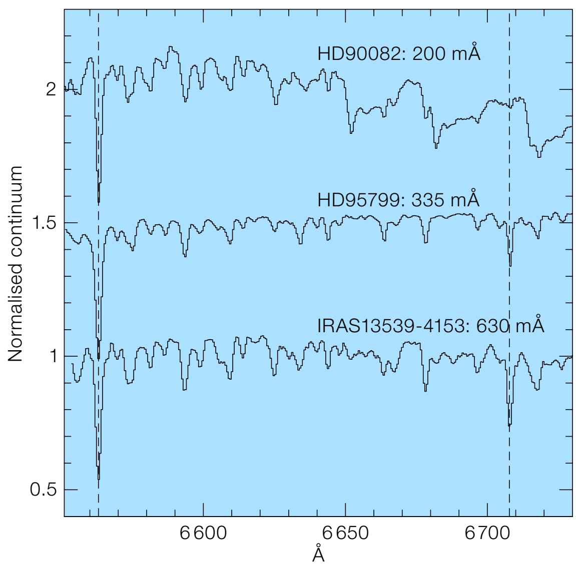

Figure 3. A portion of the spectrum of three stars with different EWs of the lithium doublet at 6707.8 Å (see the labels above each spectrum). The spectra have been obtained with the red VPHG, and the dashed vertical segments mark the position of Hα (left) and the Lithium doublet (right).

curves also offer clues on the role of interactions and their impact on evolutionary histories. Galaxy evolution in general can also be explored by comparing rotation curves of distant galaxies with those of nearby objects.

Rotation curves derived from emission lines, and in particular those of Hα and [N II] are particularly useful to derive the mass distribution in disc galaxies, because they trace the motion of interstellar gas of the young population (H II regions). This gas has a velocity dispersion (of the order of 5–10 km/s) that is much smaller than its rotational velocity, allowing accurate measurements. Among spiral galaxies, giant spirals seem to be the best laboratories to study the structure and kinematics (see Figure 5). They have extended discs and rotational velocities up to ~ 400 km/s. Through their rotation curves we can study the angular momentum properties and the DM distribution on the 100 kpc scale.

To measure rotation curves of giant spiral galaxies we took spectra of two objects with the red VPHG. A 1200-sec exposure was made of the giant spiral UGC 5711, with the slit oriented along its major axis (see Figure 4). A portion of the 2D spectrum near Hα is also shown in Figure 4. The differential velocity can easily be seen on the frame, and the rotation curve is plotted in Figure 5 out to ~ 30 kpc. The figure shows that the systemic velocity is compatible with that of the RC3 catalogue, and that the precision we obtain is comparable to that of standard studies of this kind.

The same exercise was done with PGC 048532, whose rotation curve is also displayed in Figure 5. As for UGC 5711, the quality of the data is very good out to 10 kpc. For this galaxy, Yegorova et al. (2008, in preparation) obtained an independent rotation curve with a 2 × 2 000 sec spectrum collected with grating 6 of the EMMI/REMD arm. The resolution was 4 900 with a slit width of 1″. The resulting rotation curve is shown with open circles in Figure 5. It is clear that the two curves are consistent with each

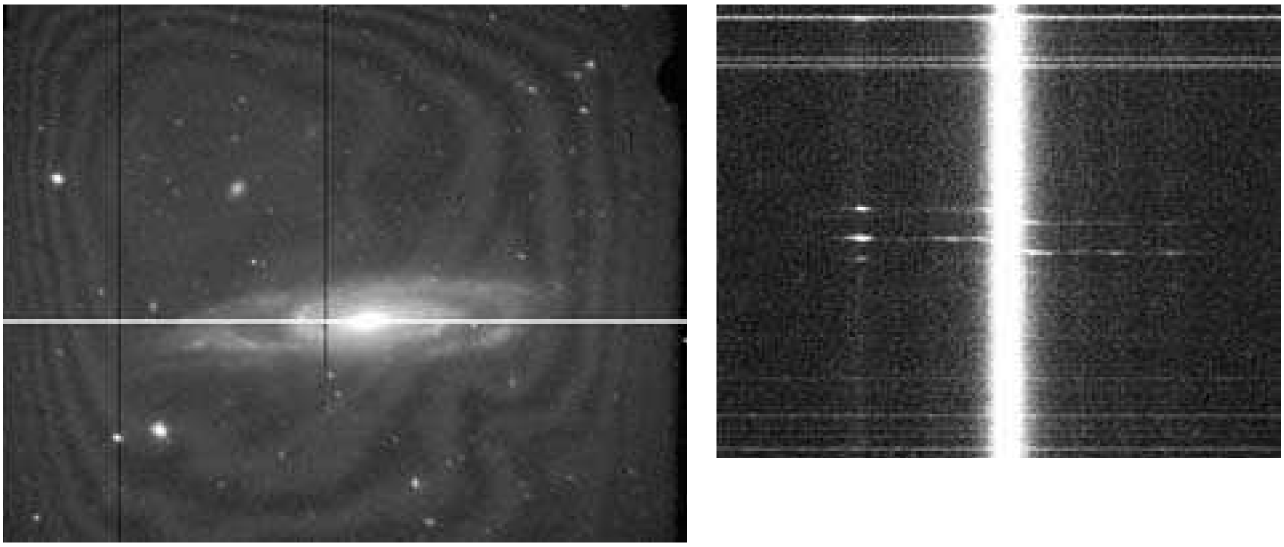

Figure 4. The left panel contains the acquisition image of UGC 5711 in white light, showing the location of the slit across the galaxy. The right panel shows the wavelength-calibrated and distortion-free spectrum in the region of Hα. The wavelength increases upward.

other, demonstrating the suitability of the red VPHG for this kind of study. Moreover, the EFOSC2 result was obtained in a 70 % shorter exposure time.

Caveats

To make the best use of these grisms, users must be aware of the following issues. The flat-fields of both grisms show gradients in the cross-dispersion direction. These gradients are also wavelength-dependent, which means that the response functions depend on the position along the slit. For point sources, an accurate flux calibration then requires the spectrum of spectrophotometric standards to be obtained in the same position as the targets. For extended sources the spectrophotometric standards should be placed in different positions across the CCD, or corrections to some fiducial response function should be obtained based on flat-fields. Second order contamination is apparent in the red grism for $\lambda > 6800$ Å, so it is advisable to use order-sorting filters to cut out the blue flux, if flux calibration is an issue for the science case. Note also that the spectral range of the blue grism does not reach the Mg triplet at 5 200 Å or the *G*-band at 4 300 Å. However, using the movable slit we verified that the two features can be reached with a slit offset of 15 mm in either direction (the dispersion is 14.5 Å/mm). Therefore two additional sets of slits were made, with 15 mm offsets to the blue and to the red, with respect to a central slit. They can be used to cover a more interesting blue spectral range, by merging two spectra.

Acknowledgements

We thank Irina Yegorova and Alessandro Pizzella for computing the kinematic data of the spiral galaxies.

References

Cameron, A. G. W. & Fowler, W. A. 1971, ApJ, 164, 111
Charbonnel, C. & Balachandran, S. C. 2000, A&A, 359, 563
Dhillon, V., et al. 2007, The Messenger, 127, 41
Uttenthaler, S., Lebzelter, T., Palmerini, S., et al. 2007, A&A, 471, L41

Figure 5. **Left:** The rotation curve of UGC 5711 measured with the red VPHG. The dotted line shows the recession velocity of 6264 km/s from RC3. **Right:** The rotation curve of PGC 048532 measured with the red VPHG (filled diamonds + error bars) compared to the result (open circles) obtained with EMMI by Yegorova et al. (2008, in preparation). The dotted line shows the recession velocity of 8587 km/s from RC3. The physical radii have been computed assuming H_0 = 72 km sec^{-1} Mpc^{-1}.