Interference filters allow the study of extended objects

Swetlana Hubrig and Gerardo Avila

Planetary nebulae have been imaged using a new facility at the Very Large Telescope.

The use of large-aperture telescopes of 8–10m class, coupled with high-resolution, highly efficient spectrographs, allows the recording of stellar spectra of unprecedented quality in the visible and near-UV region. Such instrumentation includes the UV visual echelle spectrograph (UVES) at the Very Large Telescope, the high-dispersion spectrograph at the Subaru telescope, and the high-resolution echelle spectrometer at Keck I. Observational results have been accumulating at a rapid rate in recent years. They are now used to critically examine the theoretical assumptions underlying models that have been developed for a wide range of astrophysical problems (e.g., cosmological models, stellar evolution models, nucleosynthesis, etc.).

In Spring 2006, eight interference filters were offered for use with the high-resolution spectrograph UVES installed at the Nasmyth focus of the Kueyen, Unit Telescope 2 of the VLT array on Cerro Paranal. The scientific aim of the installation of interference filters in UVES is to study faint extended objects, for example planetary nebulae (PNe) or H II regions that are beyond the limit of a 4m class telescope. PNe are important tracers of intermediate-age stellar populations in galaxies because they are the result of asymptotic giant branch (AGB) mass loss and their birth rate is very likely a function of metallicity. Therefore, a spectroscopic study of the physical conditions and chemistry of PNe and H II regions is crucial to understanding metal enrichment during the galaxy’s lifetime.

PNe are known to display a variety of morphological components such as multiple shells, extended halos, knots, bipolar lobes, jets, and rings. The detailed analysis of the structure of these components provides an important insight into the processes governing PNe formation and evolution. The most important parameter needed to describe the dynamics and various morphological components is the velocity field derived from spatially resolved PNe. Numerous recent studies are aimed specifically at disentangling the full velocity fields by high-resolution spectroscopy: an example is a study of the structures of faint extended ionized halos of PNe. These are believed to reflect the previous history of heavy mass loss on the AGB, and require precise knowledge of internal velocity fields. The availability of the high resolution UVES long-slit mode affords the opportunity to carry out an accurate kinematic analysis of faint halo structures and their puzzling systems of rings discovered in HST images. Currently, only very few other high-resolution spectrographs at 8–10m class telescopes in the world have a long-slit capability. Thus, by introducing the high resolution long-slit mode in UVES, adding interference filters to remove the other orders, and taking advantage of the full slit length of 30 inches, should be of great interest to people working on the kinematics of ionized nebulae and galaxies.

The central wavelengths of the interference filters were chosen to permit observations of the most important emission lines in extended objects. The order for the filter manufacture was placed with the Andover Corporation in March 2005 and the filters arrived in Garching in June 2005. All eight filters were installed...
in the UVES red filter wheel in August 2005. The filters and their central wavelengths are Hα (656.6nm), Hβ (486.1nm), OIII (500.7nm), OIII (436.3nm), NII (575.5nm), OI (630.0nm), SII (672.4nm), and HeII (468.6nm). Transmission measurements for all filters were done with the Cary spectrophotometer at the end of June 2005. Most of the filters were found to be within the specifications and all central wavelengths matched the specified values very well. All the transmissions, with the exception of the OIII 4363 filter, have been larger than 70%. In all cases, the full-width half-maximum (FWHM) was also found to be bigger than the specifications. The FWHM of the Hα filter allows simultaneous observations of Hα with nearby [N II] lines with wavelengths at 654.8nm and 658.3nm. The chosen FWHM of the SII filter permits simultaneous observation the [S II] 671.7/673.1nm doublet.

The first sky test with the new filters was carried out in August 2005. The planetary nebula NGC 6369, which has a diameter of the order of 30 arcsec, has been observed with the UVES red arm using CD#3 and a slit width of 0.6 arcsec (resolving power $R = \lambda / \Delta \lambda \sim 70,000$). The slit viewer image of this nebula is shown in Figure 1. At present there is no pipeline support for the reduction of the UVES long-slit mode, so the spectra have been reduced using both MIDAS (Munich image data analysis system) long-slit software and the IRAF (Image reduction and analysis facility) package for the long slit case. We present the final two- and one-dimensional Hα and Hβ spectra of NGC 6369 in Figures 2–3. Our sky tests of the interference filters showed that the UVES long-slit mode configuration can be used successfully for observations of extended objects with narrow spectral features.

**Figure 2.** Shown is the Hα spectrum of NGC 6369.

**Figure 3.** Shown is the Hβ spectrum of NGC 6369.

**Author Information**

Swetlana Hubrig  
European Southern Observatory  
Santiago de Chile, Chile

Gerardo Avila  
European Southern Observatory  
Garching, Germany

**References**