Chapter 7

The dataset of the longterm-monitoring program

Soon after the discovery of comet Hale-Bopp an optical longterm monitoring program was initiated by Rauer *et al.* [1997, 2002]. Observations started in April 1996 and ended nearly 5 years later in January 2001. Observations before perihelion cover the heliocentric distance range from 4.6-2.8 AU, while the observations after perihelion cover the range from 2.9-12.8 AU. This was the longest campaign ever observing a single comet in the optical wavelength range. There is a gap between 2.6 AU pre-perihelion and 2.9 AU post-perihelion. For most of this time Hale-Bopp was not observable at night, because it was close to the Sun. Only close to perihelion was a short opportunity to observe the comet and the optical longterm monitoring program was complemented by observations during the perihelion passage. As part of the 'International time project' the comet was observed using telescopes on the Canary Islands. However only data from the longterm monitoring have been used for this work.

Depending on the telescopes and instruments, longslit-spectroscopy and imaging was performed in the longterm monitoring program. The spectra obtained cover typically a wavelength range from 3800-7600 Å. Images were obtained using R-, B- and V-filter. The images serve a number of purposes. They allow to analyze the morphology of the coma as has been done by Boehnhardt *et al.* [1999]. For this work the images have mainly been used to verify the positioning of the slit. Furthermore the general activity of the comet can be checked. Outbursts can be identified. The outbursts known from this comet are also short, i.e. less than a few rotation periods, i.e. no more than 2-3 days [Boehnhardt, pers. comm]. Therefore, the gas of such an outburst will disappear quite rapidly from the coma. The dust can stay much longer, thus the images allow to determine whether and when an outburst happened.

Observations were obtained at a number of different telescopes (see Table 7.1), mainly at the European Southern Observatory (ESO). All of the post-perihelion observations and some of the pre-perihelion observations were done in service mode.

In the following a very brief description of each telescope is given. For technical data like slit length or field of view see Table 7.1.

Location	Telescope Instrument	FOV	slit-length	spatial scale [arcsec/pix]
La Silla, Chile	Danish 1.54m DFOSC	13.7' × 13.7'	13.7'	0.39
	ESO 1.52m Boller&Chivens	-*	4.5'	0.82
	ESO 2.2m EFOSC2	5.7 × 5.7	5.7'	0.16
	ESO 3.6m EFOSC2	5.7 × 5.7	5.7'	0.16
Paranal, Chile	VLT (UT1) FORS1	6.8' × 6.8'	6.8'	0.20
Haute-de-Provence France	OHP 1.93 Carelec	-*	5.5'	1.1

Table 7.1: Telescopes used in the longterm-monitoring program. The asterisks indicates no imaging capability

ESO 1.52m The telescope is essentially a twin of the 1.5m telescope at the Observatoire de Haute Provence. It is mounted in an English cradle and is used at the f/14.9 Cassegrain. The Boller & Chivens Spectrograph (B & C) has no imaging capabilities.

Danish 1.54m The Danish telescope was built by Grubb-Parsons, and has been in use at La Silla since 1979. The telescope has an off-axis mount, and the optics are of Ritchey-Chretien design. On account of the telescope's mount and the limited space inside the dome, the telescope has significant pointing restrictions. The Danish Faint Object Spectrograph and Camera (DFOSC) is a focal reducer type spectrograph/camera similar in concept and in layout to ESO's EFOSC1 and EFOSC2. The spectra of comet Hale-Bopp obtained at this telescope show a strong straylight pattern on the CCD due to reflected and scattered light within the optics. The effect severely limits the quality of spectra below a wavelength of approx. 4500 Å (see figure 7.1).

ESO 2.2m The 2.2m telescope at La Silla has been in operation since early 1984 and is on indefinite loan to ESO from the Max-Planck-Gesellschaft. The telescope (which is a fork mounted Ritchey-Chretien) was built by Zeiss. The ESO Faint Object Spectrograph and Camera (v.2) (EFOSC2) is a versatile instrument for imaging and spectroscopy. Its high efficiency makes it an ideal instrument for low resolution spectroscopy. It was transfered to the ESO 3.6m in October 1997.

ESO 3.6m The 3.6m telescope was commissioned in 1977. It has a horseshoe/fork mounting. It was designed with interchangeable top-units allowing change over of secondary mirrors to go from prime to Cassegrain or Coudé focus. For this work the EFOSC2, formerly in use at the ESO 2.2m telescope (see above), was used at the Cassegrain focus.

VLT/UT1 The ESO Very Large Telescope (VLT) consists of an array of four 8-meter telescopes which can work independently or in combined mode. For this work only Unit 1 (UT1) named ANTU ('The Sun' in the Mapuche language) was used. The unit has alt-azimuth mount. The VLT optical layout is of the Ritchey-Chretien type and was operated in the Cassegrain focus. The FORS1 instrument is designed as focal reducers multi mode instrument. For this work only the imaging and the low resolution spectroscopy mode have been used.

OHP 1.93m The telescope is located in Haute-Provence in the south of France. It is a 1.93m telescope commissioned in 1958 and serviced completely in 1985 and 1993. It is mounted in an English cradle and used at the (f/15) Cassegrain focus. The CARELEC spectrograph has, like the B & C, no imaging capabilities.

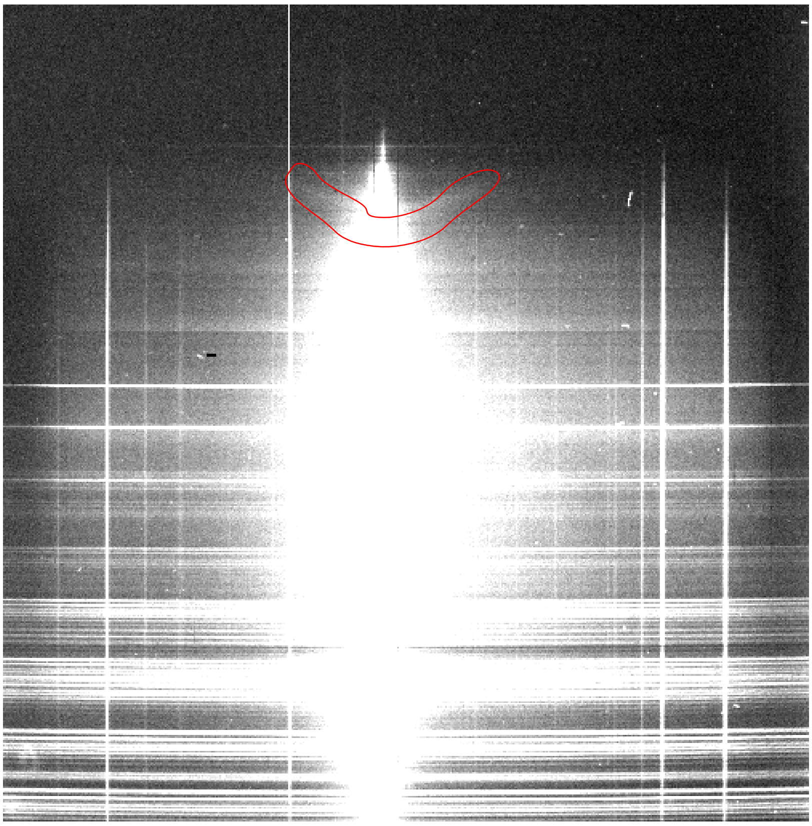

Figure 7.1: Spectrum obtained at the Danish 1.54m telescope on April 25, 1996. The approximate location of the reflex is marked in red. The horizontal axis shows the spatial direction, the vertical axis the dispersion direction

A tabulated description of the dataset is given in table A.1 on page 222. A total of 60 nights have been observed, yielding approximately 140 spectra of comet Hale-Bopp. The

temporal coverage pre-perihelion was good, with an observing run about every months. Post-perihelion, however, there is a gap in the coverage during the summer of 1998. Due to an usually strong El Niño a number of observing runs have been lost due to weather conditions. The situation improved in autumn of 1998 and using the ESO 3.6m telescope good quality data good be obtained again. The monitoring campaign was concluded , after 3 consecutive observations using the VLT/UT1 between April 2000 and January 2001, did not show any emissions of CN anymore.
In addition to the sciences exposures a number of calibrations frames have been obtained in each night. A nightly observing run included at least the following calibration items:

Bias frames Ideally read out of the electronics while the CCD is disconnected. Most telescopes do not allow to disconnect the CCD therefore bias frames are obtained by reading out the CCD with closed shutter and an exposure time of 0 sec. As many bias frames as possible are obtained, evenly distributed over the night to detect possible trends with time.

Flatfields Spectrum of a uniformly illuminated screen or the twilight sky (in case of images), for each optical setup (combination of slit+grism+filter) used. Usually obtained at the beginning and the end of the night.

Wavelength calibration Spectrum of a calibration lamp. When possible obtained in the same telescope position as the observations, to minimize effects due to flexure of the telescope.

Sky background Spectrum of the night sky, offset from the comet at the same elevation. Close in time to the observation of the comet.

Spectrophotometric standard star Spectrum of a spectrophotometric standard star. At least 2 exposures to allow a control of the absolute calibration. Stars should be observed at approximately the same airmass as the comet.

Table C.1 in appendix C gives an overview of all spectrophotometric standard stars used in the observing campaign.