New Focussing Tools

Considering that fast focussing techniques allow observers to save time by being able to gather more scientific data and therefore be more efficient, we have investigated new methods for focussing CFHT instruments. Two new tools are now operational. One is a fully automatic focussing program for instruments with an imaging mode and use the prime focus bonnette, e.g., FOCAM and HRC. The same program can also be used in a semi-automatic mode for instruments not using the prime focus bonnette, like FOCAM and TIGRE at the Cassegrain focus. The second automatic focussing tool is dedicated to the focal reducers in their PUMA and PALILA applications and will be used in the coming MOS/SIS.

Automatic Focussing at Prime Focus

Imaging at prime focus is probably our most demanding application for focussing due to the large number of filters that can be used at any one time (12), and to a short mean time between large telescope motions requiring re-focussing (the need to focus if the telescope is moved by more than 30° is generally adopted). With old focussing methods, one had to spend 10-15 minutes to reliably focus each filter, which clearly becomes a burden even for typical broad band filters imaging runs using the standard BVRI set.

We have developed, and successfully implemented during the May 1990 prime focus FOCAM run, a fully automatic focussing procedure which takes a total of 4 minutes per filter to scan for the best focus for a typical set of 8 ten second exposures. The algorithm performs a sequence of 3 to 8 exposures, computes the best focus position, and then moves automatically to this position. The new tool can be invoked from the "CAF" (Computer Aided Focussing) button on the data acquisition HP9000 workstation.

The steps one should use are the following:

(1) Locate a focus star of appropriate magnitude to allow for exposure times longer than 10 sec (typically m=12).

(2) Lock the telescope on a guide star.

(3) Use the video focus mode to move the bonnette focus close to the optimum (within a few tenth of a mm).

(4) Select the exposure time, the number of exposures, and the bonnette focus step to apply between exposures.

The automatic sequence is then started. The routine assumes that the focus choice in video mode, plus the step increment and number of exposure selections, will ensure that the best focus will be included in the scan. The focus is moved to the lower end of the scanning range, an exposure of the given exposure time is taken, and the bonnette focus is moved by the given step before taking the next exposure. When the sequence is complete, a plot is displayed of the FWHMs in the X and Y directions as measured on each frame vs. the bonnette focus position (Figure 6). The plot also indicates the best focus position (computed as the mean of the focus positions of the best X and Y FWHMs) as well as the corresponding best FWHM. If satisfied with the

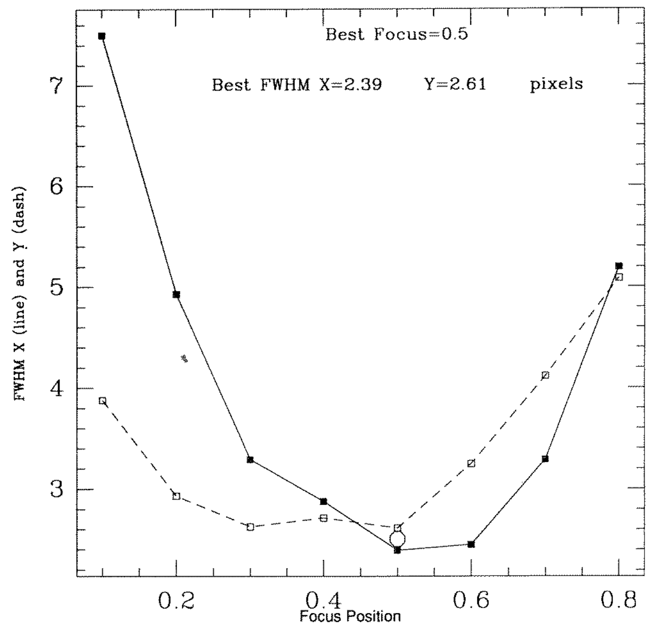

Figure 6

computer's selection, one has then to type "q" in the plot window for the bonnette to move to the best computed focus position. An option is present to allow you to display an image mosaic created from the individual focus frames; this takes an extra 1.5 min, and has been rarely used since, as the sequence images are taken, they are displayed one by one for visual evaluation on the CCD controller TV monitor.

This routine has worked very well and has been used extensively during its first try May 20 to 29 1990. A few improvements have been suggested by staff and visitor users. For example, there is a need to tell the observer that the instrument is too much out of focus for use of the automatic routine. Also, it might be necessary in certain conditions to take multiple exposures per focus position in the case of large seeing fluctuations (although a proper exposure time should be able to "smooth out" short term seeing fluctuations). One would also like to automatically offset the focus by a known (calibrated) amount when changing from one filter to the other in the standard UBVRI filter set. We plan to include these improvements as soon as possible.

When an instrument does not allow any computer focus control, as is the case with FOCAM and TIGRE at the Cassegrain focus, the same method can still be used. In this case, however, the routine turns itself into a semi-automatic mode, and prompts you to move the focus between each exposure of the sequence and at the end to the best focus position.

Computer Aided Focussing with Focal Reducers

A simple optical tool has been used since the second semester 1989 on the PUMA focal reducer mounted at the Cassegrain focus. For focussing one has to insert into the beam a mask with two holes, one empty and one with a prism, which produces 2 images for any given star. The relative image motion between the two images of a given couple is then directly related to the telescope focus motion via a simple calibration coefficient.

The steps used for focussing are now the following:

1) Insert the focussing mask in the beam.

2) Take an image with a long enough exposure time to show several stars in the field (a typical 60 second exposure is generally enough on any field even at high galactic latitudes).

3) Select the "cursor/region" options in the X-image display to be able to select a few stars (3-4 minimum) with the cursor.

4) Write the positions to the default file with the "write" X-image option.

5) Select "accept" in the CAF (Computer Aided Focus) form if the default image name and position file name are acceptable.

The routine will then compute the mean offset between the star images and their double and tell you the differential focus motion to apply in telescope encoder units. In the current configuration this last step takes 1 minute due to the need to create an IRAF format image file in order to use IRAF tasks in the background. This will be shortened for the next run to a few seconds by working directly on the FITS image created by the data acquisition computer.

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Scanning Modes on PALILA

PALILA is a focal reducer type spectrograph which uses scanning Fabry-Pérot etalons to explore a small wavelength range (4 to 90Å depending on the present etalon used) in the roughly 5 x 5 arcminute field.

We currently use three etalons manufactured by Queensgate Instruments Ltd. The distance between the plates is scanned by applying appropriate voltages to piezo-electric stacks. This in turn changes the wavelengths λ transmitted by the etalon. For a ray of angle of incidence i on the Fabry-Pérot their values are given by the (deceptively) simple equation:

$$2\,n\,e\cos(i) = p\,\lambda(i)$$

where n is the air index of refraction and p any positive integer. Of course, in practice, an interference filter is used to select a wavelength range, and then sets a particular value of p.

In actual use, the voltages are put by sending a binary control value (BCV) to the etalons CS 100 controller, which can vary between -2048 and +2047. This changes e according to an accurately linear relationship.

Three different scanning modes can now be used.

(1) "Manual" Scanning

The etalon is put at the required BCV, and an exposure window is opened. This is particularly useful during set-up procedures e.g. to measure the position of the rings center, and especially to obtain the value of the scanning constant C of the particular etalon used: At a wavelength λ_0 (given by a discharge lamp) a full interference order scan is obtained for a BCV change Δ_0. $C=\lambda_0/\Delta_0$ is nearly independent of wavelength, and can thus be used to compute the required BCV to scan an interference order at any wavelength λ.

(2) Full Automatic Scanning

Three parameters are entered: the scanning constant C, the central wavelength λ and the number of equidistant steps n. n identical exposures are then automatically made. A full interference order is scanned, through a total BCV scan of λ/C, centered on BCV=0. Two slightly different modes can be selected, a full scanning with overlap (i.e. the last channel is in phase with the first channel), or without overlap. Possible variations of atmospheric transmission (and of the strengths of the night sky emission lines) during the whole sequence are quite troublesome. To minimize their effect, the channels are scanned in an interlaced sequence.

This mode is generally used with high interference order etalons, like the CFHT p=1162 at Hα, with a free spectral range (or full scanning range) of only 5.6Å.

(3) Partial Automatic Scanning

With a low order etalon, like the CFHT p=72 at Hα, the free spectral range is so large (91Å) that it becomes more efficient to scan only a limited range, centered on the radial velocity of the galaxy studied. From a preliminary calibration with a discharge lamp, one enters the following parameters: λ_c the calibration wavelength and B_c the BCV value which puts λ_c at the center of the field. For observing, one enters the start wavelength λ_s, the end wavelength λ_e and the number of equidistant steps n.

The (λ_s -λ_e) interval is then scanned with a similar interlaced sequence. To put a wavelength λ at the center of the field, the required BCV value is:

$$B = B_c + 1/C\,\{\lambda * \mathrm{INT}\,(p_c\lambda_c/\lambda) - p_c\lambda_c\}\ (\text{modulo}\ \lambda/C) \quad (2)$$

A number of different algorithms have been developed, with the help (and friendly pressure) of B. Tully from the University of Hawaii, to avoid occasional large jumps in BCVs when possible (i.e. when the total wavelength range to scan is not too large).

In principle it is possible to calibrate this scanning procedure at any wavelength λ_c. However, there are small phase effects, due to chromatic variations of the plate separation e in such multi-layer coated etalons. It is thus highly recommended to use a calibration wavelength close to that of the object.

Following the use of a CCD detector early 1988, these three scanning modes have been put into use, through the HP9000 based DAIC system, in March 1990.

Further details on the operation of the system can be found in the appropriate User's Manual ("Scanning Fabry-Perot Spectrography with the PALILA focal reducer").

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