

# A little CHARM description

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<http://www.mpia-hd.mpg.de/MPIA/Projects/CHARM/index.html>

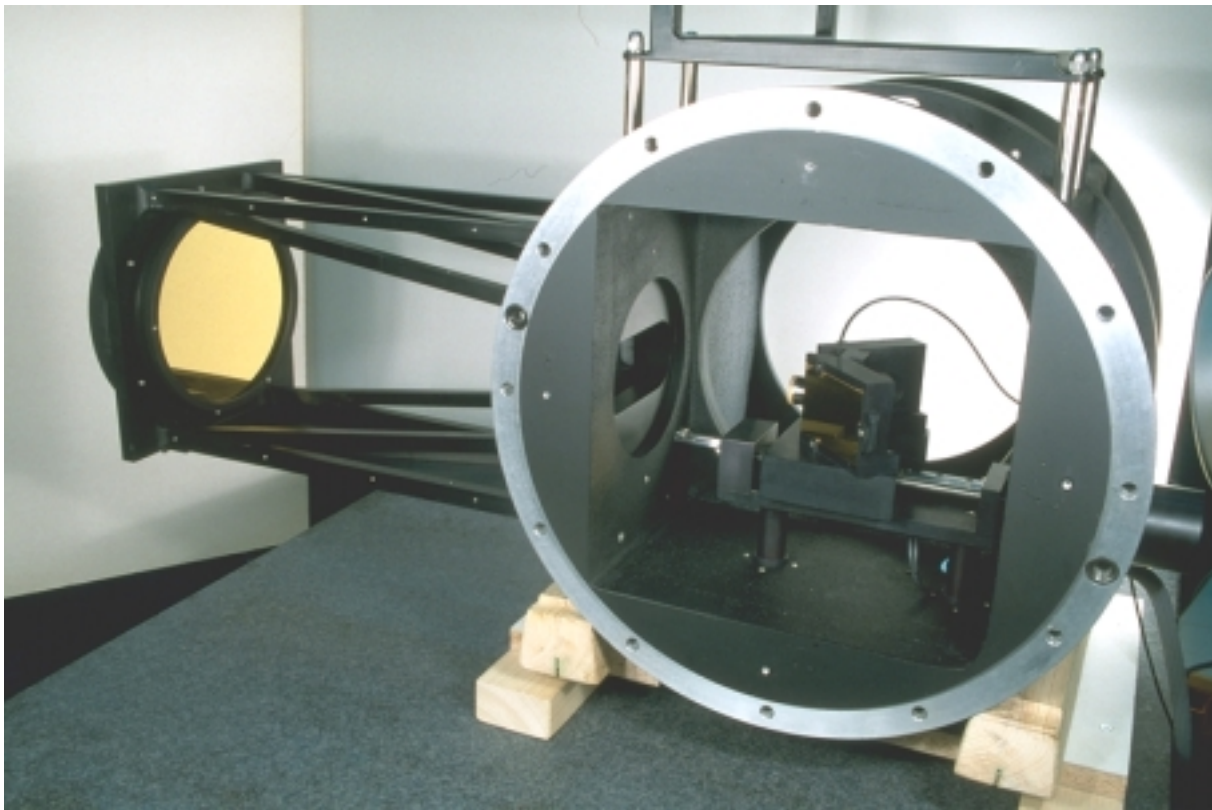


Figure 1: Photograph of the CHARM instrument

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# 1 The beginning

## 1.1 Switching on and login procedure

1. Switch on the CCD controller (AstroCam electronics) on one side of the Cassegrain flange and the motor-piezo controller on the other side. The motors will then run to their zero positions. Wait until all motors stop moving.
2. Login to *waipi* either directly on *waipi*'s console or via an X-Terminal (choose *waipi* within the Chooser). Login as *charm* (for password ask local staff). Open *console@keahua* in Workspace in SHtools (click the right mouse button anywhere on the root window to popup the Workspace menu).
3. Switch on the VME crate *keahua*. All messages from the VxWorks system are displayed in the *console@keahua* window. When resetting the VxWorks system all the messages are scrolling over the blue *console@keahua* window. During normal operation there is no information of interest in the console window so it can be closed.

## 1.2 GUI's

Back to the xterm window, type *astroCam.tcl* & to open the main GUI.

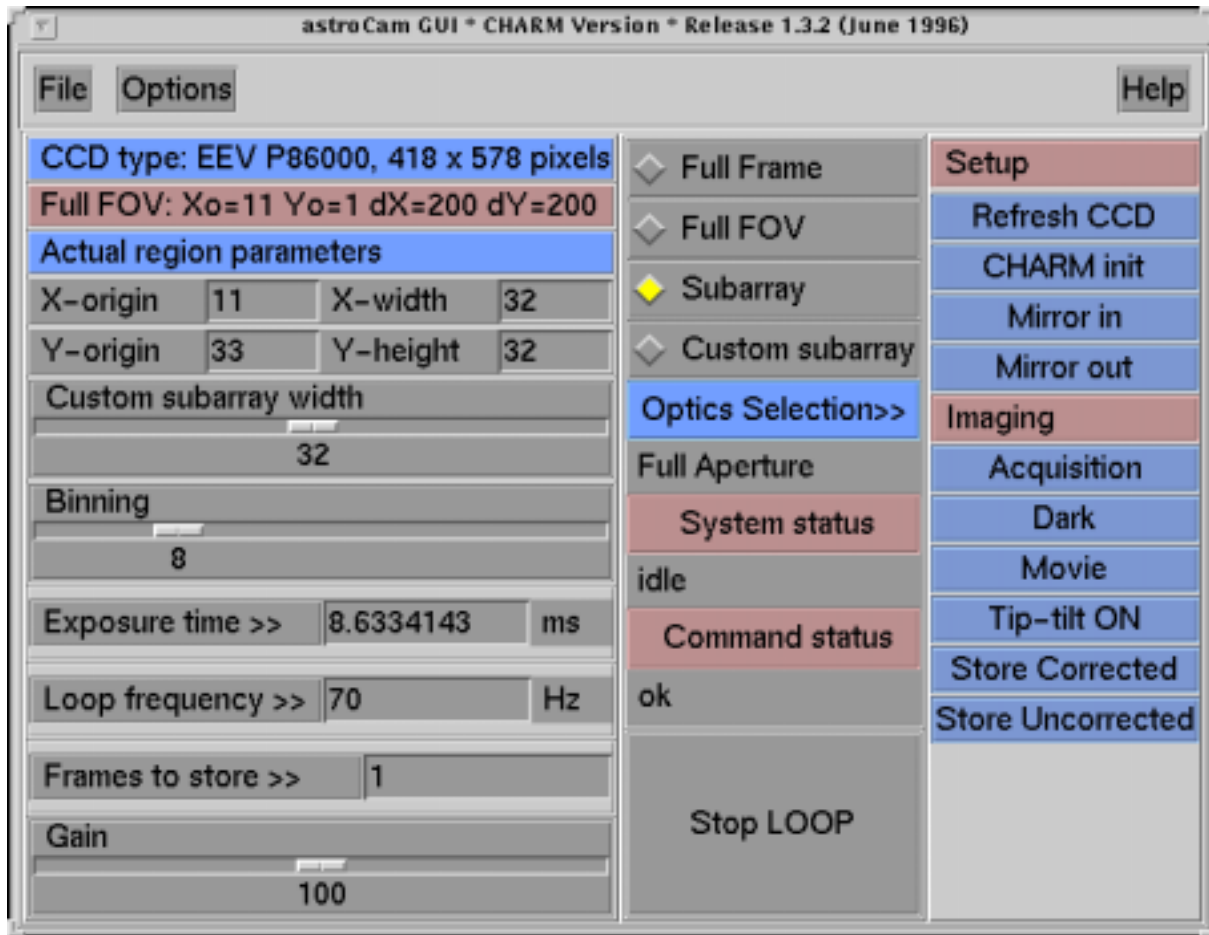


Figure 2: CHARM's main GUI

There is more detailed information on the encoder positions of the motors in an EPICS based GUI that is opened by typing *charm*. The salmon coloured window (all colours courtesy of Stefan Hippler) displays the actual positions of the four motors in the system and allows you to move the folding mirrors in and out, and to choose the aperture/lenslet ( As of today (June 30, 1996) there is only the standard achromat in the *small aperture* position.)

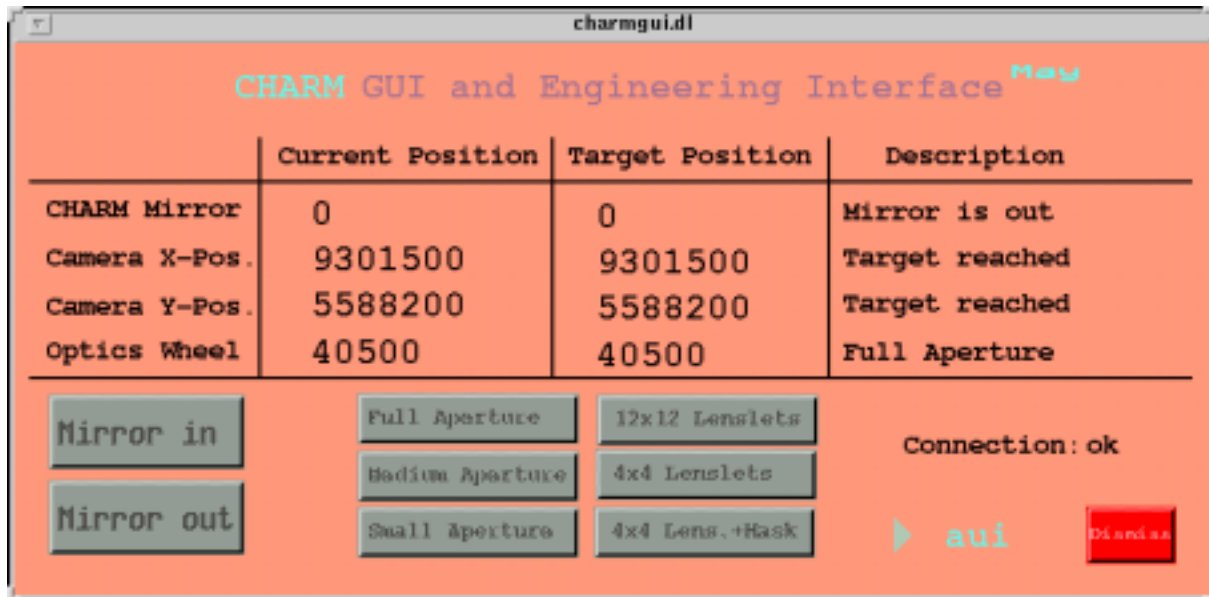


Figure 3: CHARM's motor status and control panel

### 1.3 First initialisations

Now, click on **CHARM init** on the top right (always use the left mouse button). The *astroCam.tcl* GUI will then inform you that the system status is **busy** and that the command status is **sending command**. If the salmon coloured *charm* GUI is open you will now see that the mirrors are moved out ( target position 0) the camera x and y coordinates approach some number in the 630000 range and the small aperture (position 81300) is chosen. Unless there are problems or you want to see what is going on there is no need to have the *charm* GUI open.

When all the motors have reached their final positions, the system status in the *astroCam* GUI switches to **idle** and the command status is **ok**. CHARM is now set up and we proceed by adjusting MAGIC.

### 1.4 Optical alignment

After having done the whole adjustment procedure for MAGIC, move **Mirror in**. Note that the image on MAGIC will flip, i.e. left and right are swapped, when CHARM is in. Thus, when moving the telescope with MAGIC's GUI by clicking on stars remember that instead of moving from right to left the star will move the other way. (This is not a bug it's a feature.) To adjust CHARM, click on **Full FOV** to choose the usable area of the CCD and start **Movie**. After a few seconds, a

window appears with the CCD camera image. This image is being refreshed every few seconds.

*To exit from the Movie mode move the cursor into the image and type `q` for quit.*

Normally, the star that you used to adjust MAGIC should appear in the center of the CCD camera image. Use the middle mouse button to move the star on the CCD by clicking first on the actual position of the star (the *from where* position) and then on the position where you want the star to be moved to (the *to where* position). Now, defocus the telescope as you did for adjusting MAGIC's tilting flange and check whether the pupil looks nice. If it doesn't, fiddle with the 3 bolts under the collimator in front of the CCD until it looks nice. Then, focus the telescope to the position determined with MAGIC.

*CHARM is now fully adjusted.*

## 2 Tip-tilt correction

### 2.1 Finding the star

Find your object with MAGIC and use **Movie** in **Full FOV** mode to check it. Move the guide star into the default subarray box by clicking on the star with the right mouse button. The default subarray is in the upper left corner. This is the optimal position for minimising the readout time of the subarray.

If the star cannot be moved into that box, define a new subarray by clicking on the star with the left mouse button. Now, typing `q` inside the image window automatically invokes the **Custom subarray** mode in the GUI. The **Custom subarray width** can be adjusted by moving the slider. Using **Movie** again reads out exactly the newly defined subarray.

If the default subarray is fine click on **Subarray** to define this part of the chip for the next imaging action.

### 2.2 Checking the readout parameters

To achieve a high loop frequency, the shutter of the CCD camera has to stay open and the camera is operated in a kind of frame transfer mode (see section Imaging modes). As the exposure is slightly different in the shutter modes like **Movie** and

in the 'frame transfer modes' one has to take images with **Store Corrected** before starting the final **Tip-tilt ON** for unlimited correction.

**Store Corrected** reads out a limited number of frames that has to be specified in **Frames to store**. The >> indicates that by clicking on the text **Frames to store** a popup menu gives a selection of numbers that can be chosen. Once **Store Corrected** is started it cannot be stopped.

*Be careful not to choose 1 second exposure time and 4096 frames: that keeps the system busy for more than an hour. Then, the only cure is resetting the VxWorks system.*

One should aim at using a **Loop frequency** of at least 50 Hz, and to have an exposure time of at least the readout time. This can be checked by roughly estimating the cycle time as the reciprocal of the **Loop frequency**, and compare it to the **Exposure time**. At 50–70Hz, the exposure time is usually larger than the readout time.

As all images are stored when using **Store Corrected** the images are displayed at the end of the sequence. The display style is defined by AstroCam. They call it *tile image* because the images are displayed like tiles on the wall. Use the mouse to check whether the number of counts is alright and the stars look nice, *i.e.* round. As the tip-tilt correction is on in this mode the star should be spread out equally over the four central pixels. If you have counts between 2000 and 50000, with the background being set to 1000, things are fine. If the counts are too high, choosing a lower binning factor reduces the flux per pixel.

At the end of the **Store Corrected** sequence, two graphs with two curves each pop up. The first shows the centroid positions (in CCD pixel units) that should all be around zero, the second shows the piezo commanded positions that have to be between 0 and 4095. If the latter curve is a straight line at 0 or 4000 that means that the piezo has reached the limit of its throw. The star has to be repositioned in its subarray, by using the middle mouse button in **Movie** mode. One exits from this display by moving the mouse into the xterm window that was opened with the graphs and hitting the return key.

### 2.3 Tip-tilt ON

One can now guide on that star by clicking on **Tip-tilt ON**. The real-time image centroids are displayed in another salmon coloured GUI that can be activated either

by typing *au* or by clicking on **au** in the *charm* GUI.

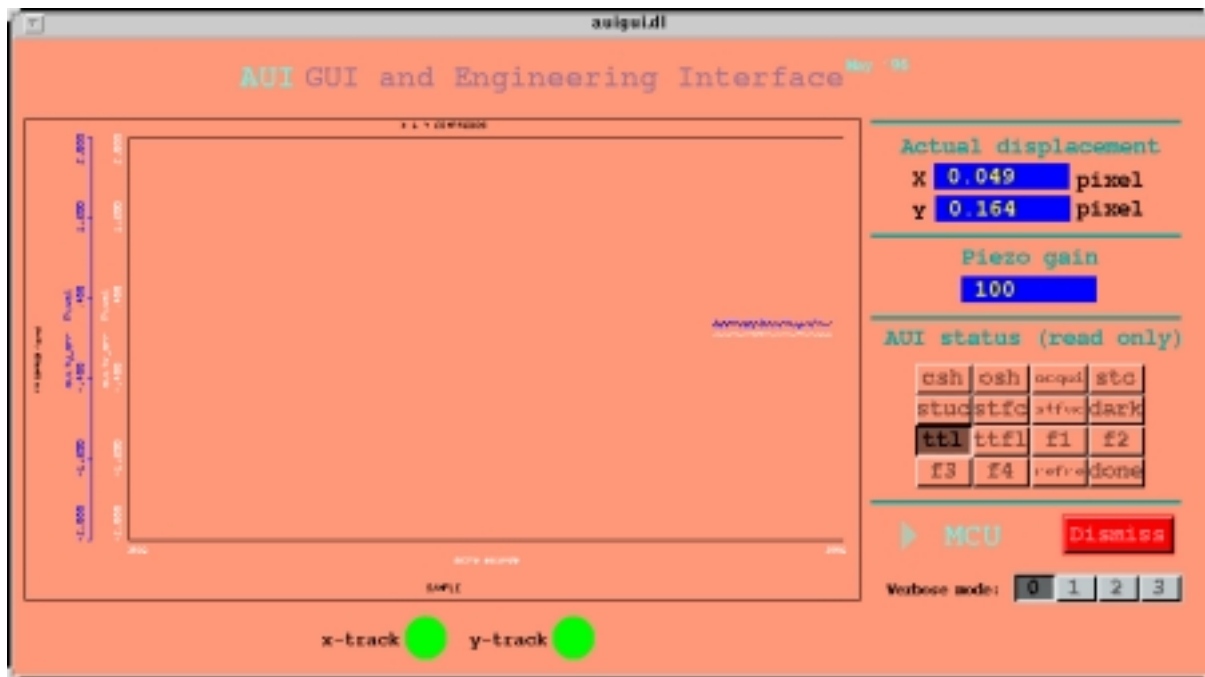


Figure 4: CHARM’s “Tip-tilt ON” real time display

In the **Tip-tilt ON** mode, the gain can be adjusted on-line, simply by moving the **Gain** slider in the *astroCam* GUI. The effect is quite obvious. A gain of 100 should be fine but since the PZT drives are operated in open loop mode. Overcritical (gain > 100) and undercritical (gain < 100) operational modes can improve tip-tilt correction.

### 3 Glossary

#### 3.1 CCD parameters

The region of the CCD that is read out can be defined by **Full Frame**, **Full FOV**, **Subarray** and **Custom subarray**. The numbers on the left (**X-origin**, **Y-origin**, **X-width**, **Y-width**, **Custom subarray width** and **Binning**) give the detailed information. In **Full Frame**, **Full FOV** and **Subarray** mode, only **Binning** can be adjusted. In **Custom subarray** all parameters can be adjusted manually.

**Full Frame** is the total visible area of the CCD.

**Full FOV** is the part of the CCD where CHARM produces an image.

**Subarray** is the default subarray for fastest readout.

**Custom subarray** can be defined by the user either by typing the coordinates in the GUI or by using the left mouse button in **Acquisition** mode.

### 3.2 Gain

Gain is the factor (in %) of the measured image centroid position that is applied to the piezos. 100% means that the piezos attempt to put the measured centroid position to the center of the subarray. 80% means that the image centroid after correction is 20% of the measured value. Reducing the gain to values smaller than 100% provides some sort of damping and increasing the gain to values greater than 100% provides overcritical operation.

### 3.3 Optics Selection

Behind the >> of the **Optics Selection** >> button appears a popup menu that tells you which filters are available in the exit pupil plane of the focal reducer in front of the CCD camera. *Don't believe a word of it.* Only in **Small Aperture** is a lens.

### 3.4 System status and Command status

Both provide information on these stati. Messages are **Idle** and **Busy**, and **Sending Command** and **Ok**.

### 3.5 Setup

**Refresh CCD** starts blinking after 60 minutes. Clicking on that button reinitialises the CCD. This takes about 20 seconds and removes all the charge that has accumulated in open shutter modes. It's a good idea to do it from time to time, but by no means vital.

**CHARM init** moves the four motors (folding mirrors, x and y camera motors) in the standard position which are:

- folding mirrors are out
- center of CCD camera image and MAGIC image coincide

- the **Small aperture** lens is chosen

There is only need to use this button after switching on the system.

**Mirror in** and **Mirror out** moves the folding mirrors in and out.

### 3.6 Imaging modes

There are **Acquisition**, **Dark**, **Movie**, **Tip-tilt ON**, **Store corrected** and **Store uncorrected**.

**Acquisition** takes one image and displays it. In this mode as well as in **Movie** mode the shutter is opened and closed, and the middle and the right mouse button can be used to move the star on the CCD. In addition to these features, one can define a custom subarray in **Acquisition** mode by clicking with the left mouse button on the desired center position of the subarray. Then, the **Custom subarray** is invoked automatically after exiting from the **Acquisition** mode by typing  $q$  inside the image.

**Movie** is essentially the same as **Acquisition** except that it refreshes the image as fast as it can until typing  $q$  with the cursor in the image.

**Dark** takes an 'image', but the shutter remains closed. This allows you to check the background.

**Tip-tilt ON** starts the tip-tilt correction until clicking on

**Stop LOOP**. At the end, the last subarray is displayed to make sure that guiding was done on a star and not on the sky background. If the system starts oscillating the **Gain** can be set to smaller values. In the **au1** window the centroids are displayed online.

**Store corrected** takes a number of images specified in **Frames to store** and displays the centroid position as a graph and, after hitting the return key with the cursor in the underlying window, the voltages sent to the piezo as a graph. Hitting the return key again exits from this graph mode and the image displaying all the subarrays as a tile image. Here one can check the intensity in the single images.

**Store Uncorrected** does the same as above, except it doesn't correct and it doesn't display the voltages. Here, one can check in the tile image e.g. whether the star leaves the subarray.

### 3.7 Other business

The exposure time is set with exposure time. The loop frequency (the reciprocal of the sum of exposure time and read-out time and overhead) is calculated automatically according to the position and the size of the subarray. Vice versa, one can choose the loop frequency and the exposure time will be set accordingly. One should always make sure that the read out time is at least 4–5 times shorter than the exposure time. Changing the binning changes the read-out time and, thus, the loop frequency is adjusted accordingly.

### 3.8 Optomechanical schematics

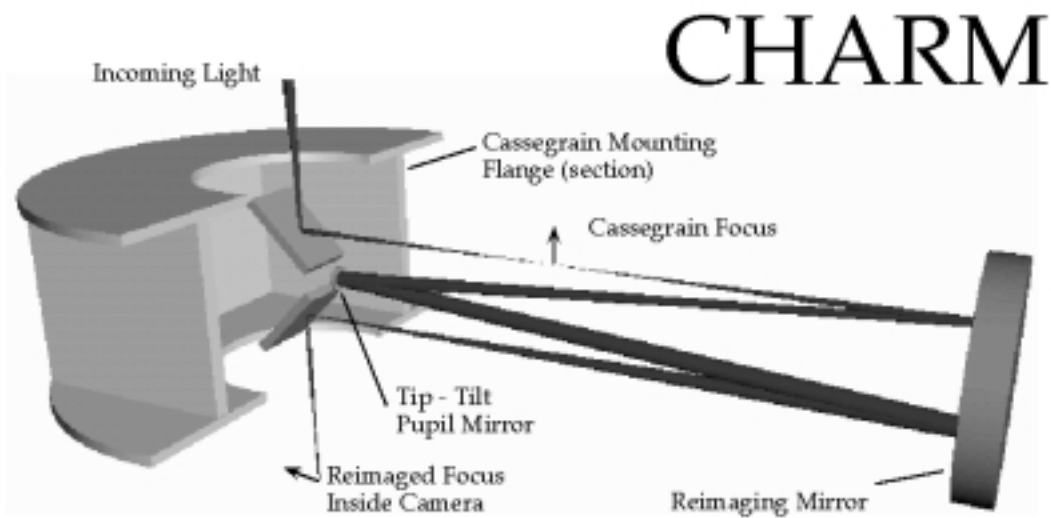
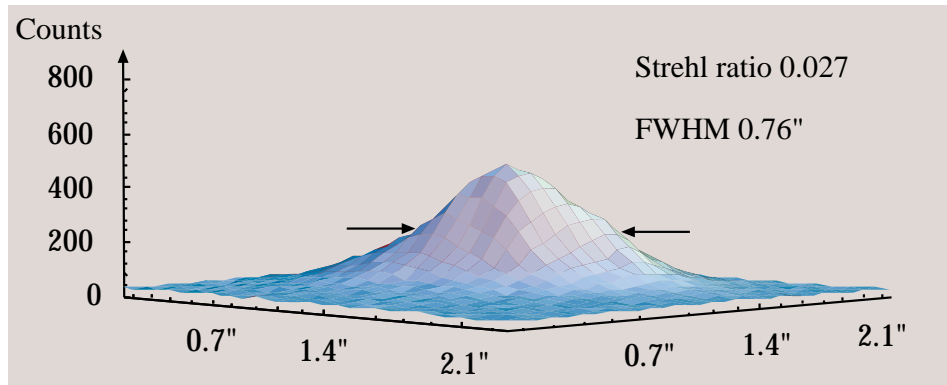


Figure 5: The optomechanical design of CHARM

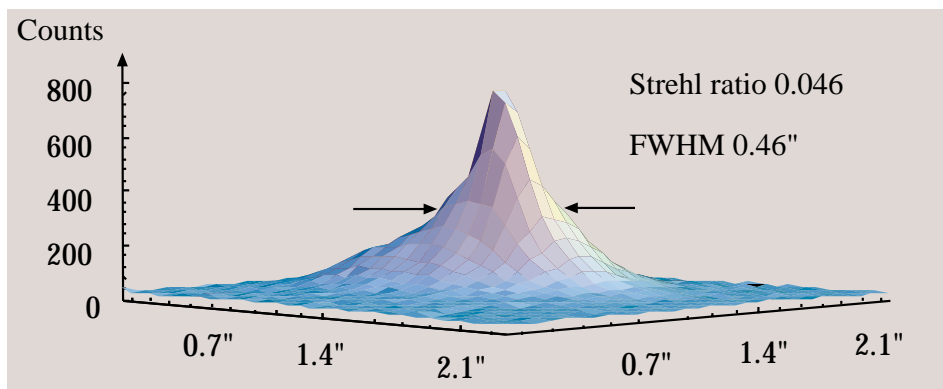
### 3.9 What you can expect

## CHARM on the Calar Alto 3.5m telescope

Seeing disk without correction:



Tip-tilt correction with CHARM @50Hz:



The images are taken with MAGIC at  $2.2\mu\text{m}$ .

The corrected Strehl ratio is exactly what the theory predicts for the achieved image stabilisation of  $0.029''$  rms image motion. At  $10\mu\text{m}$  on a  $3.8\text{m}$  telescope for the same level of image stabilisation one can expect a rise in Strehl ratio from about 60% to more than 80%.