

User Manual for the UofL CDK20 System at Mt Kent Observatory

This guide describes using the 0.5m aperture CDK20 telescope at USQ's Mt Kent Observatory, either at Mt Kent or remotely, via an X Windows server.

The UofL CDK20 system was supplied by the University of Louisville as part of a NASA funded partnership with USQ, which has become the Shared Skies project. See http://www.astro.louisville.edu/shared_skies/index.html . Reference can also be made to the Mt Kent website at <http://orion.mko.usq.edu.au/telescopes/UofL/index.html> . In particular see the Specs link.

Overview - Hardware

The **dome** is a 3.5m School Model from Sirius Observatories <http://siriusobservatories.hopout.com.au> . It is known as the Page dome, and is the third dome from the gate at Mt Kent Observatory, which is 30 minutes drive south of Toowoomba, south of the village of Cambooya. Dome rotation is monitored by RFID tags placed 4 degrees apart round the circumference, with the Phidgets reader accessed by USB. A rotation hand control with cable is hung off the rotation motor box. The upper and lower shutters can be manually controlled from the shutter control box mounted chest height, or by toggling a switch, over the network using a WiFi link. The upper shutter must be opened first and closed last.

The **telescope** is a Planewave (<http://planewave.com>) CDK20 0.5m aperture, f/6.8 corrected Dall-Kirkham design with a 3.454m focal length. This is an innovative design that provides sharp focus over a large field of view, and great temperature stability of focus due to its carbon-fibre truss.

The **primary camera** is an Apogee Alta U16M <http://www.ccd.com/pdf/U16M.pdf> , with a 4096x4096 sensor with 9um square pixels. For the OTA focal length of 3.454m, this gives 0.5375 arcsec pixels and a field of view of 36.7 arcsecs square. This camera includes two-stage Peltier cooling up to -45C from ambient. The maximum quantum efficiency is 69% at 580nm. ADC gain is 0.67 counts per photoelectron, with a 16 bit range. The maximum count of 65535 is close to the full well equivalent count of 66666. The dark current is equivalent to 0.133counts/sec at -25C, and the read noise is 6 counts at 1MHz and 2 at 5MHz (Get actual figures ???). The camera is connected by USB to the dome computer - a full frame (~64Mbytes) takes ~20s to download.

The **focuser** is a Planewave design, with a geared motor and rotary encoder. Motion by 61um is required to change the focus FWHM by one pixel. Limit switches disable excessive motion in one direction or the other. The focuser is connected to a Phidgets controller in a small box on the back of the OTA, which also holds man-off-comp switch which should be at comp for operation. The controller connects to the dome computer by USB.

The **filterwheel** is an Optec IFW-3 <http://www.optecinc.com/astronomy/catalog/ifw/ifw.htm> with a six position wheel taking 2" square filters. The filterwheel can be easily changed without disturbing the optical assembly. We have RGBL, UBVRI, griz, and narrowband filter wheels, with filters from Astrodon (see <http://orion.mko.usq.edu.au/telescopes/UofL/instspecs.html>). A hand controller is mounted on the plinth next to the telescope pier, providing home and filter select controls. Its power slide switch must be on for unit operation. The controller connects to the dome computer by a RS232 serial cable.

A **finderscope** is provided by a Watec 120N+ Monochrome Video Camera http://www.wateccameras.com/products.php?prod_id=124 with a Tamron 23FM75L 75mm f/3.9 lens. This gives 23"x27" pixels, for a field of view of 4.9x3.7 degrees. The camera is connected to a video server at <http://stv.mko.usq.edu.au/> (Login as root with password #3). A hand controller with frame-rate and gain controls is velcroed to the side of the mount. In a browser window, the camera is oriented

- The same as ds9 & xephem (left=E up=N) when the telescope is pointing W
- rotated 180 deg when the telescope is pointing E (can rotate in Video Server->Setup->Video&Image->RotateImage)

Ultra-wide angle imaging is provided by a Nikon D200 camera equipped with a Nikon AF Nikkor 75mm f/1.4 lens. This provides a field of view of 15.5 x 10.5 degrees, with 10.2M pixels (3872x2592).

The **mount** is a Planewave Ascension 200HR <http://planewave.com/products-page/mounts/ascension-200hr/> equipped with high resolution encoders directly mounted on the RA and Dec axes (additional to rotary encoders on the geared drive motors). The mount can handle up to 125kg load. A hand control is velcroed to the side of the pier (this can be used without disturbing xmtel – may have to nudge the mount from xmtel to get it to update indicators). This is a German Equatorial Mount, and crossing the local meridian (eg from east to west) requires the two axes to be moved through 180 degrees and the telescope resynced.

The **dome computer** is at crux.mko.usq.edu, and is directly connected by USB to the primary camera, focuser, ultra-wide imager and RFID reader. The filterwheel has a serial connection. Other devices are controlled over the network. A monitor and mouse and keyboard provide console access to crux. The computer can be moved forward in its rack for better access to its rear. Log in as *observer* and use password #1.

A **dome camera**, an Axis 214 PTZ ethernet camera at <http://domecam.mko.usq.edu.au>, provides high quality video with pan, tilt, zoom, focus and gain settings. The user is *root* and password is #3. The camera is mounted on the west side of the dome and looks east, so that north is to the left and the distant dome wall is the east wall.

A **dome light** can be controlled remotely to support use of the dome camera, and is toggled from <http://pagepower.mko.usq.edu.au>.

Temperature and humidity for the OTA are measured by sensors connected to the focus motor controller.

Power control is by a DigitalLoggers Ethernet Power Controller at <http://pagepower.mko.usq.edu.au> with username *admin* and password #3. This allows separate control of the following:

1. Dome
2. Dome Camera, Video Server
3. Mount
4. Primary Camera
5. Filter wheel
6. Focuser, finderscope
7. Dome light

These can also be operated by the hardware switches on the unit in the rack. Remember to leave the switches in the middle position to allow remote operation.

A **dome fan** is temperature controlled and brings in external filtered air near ground level, to be exhausted at the top of the dome, attempting to reduce summer temperatures inside the dome.

Dome flats if needed can be provided by a light box illuminating a white surface on the inside of the lower shutter.

Overview - Software

The operating system on crux, the dome computer, is the OpenSuse version of Linux. It is accessed from eg canopus in the EDG building or from a Linux system within USQ's firewall by

```
ssh -Y crux.mko.usq.edu.au
```

From outside the USQ firewall, the user will need to make a VPN connection to the USQ Linux machine *stardust* first.

Some programs are run instead on the mtkent1 server at the observatory.

The control/analysis software for the system is open-source, and mainly developed by Dr Kielkopf and Karen Collins from University of Louisville. Most code is in C or Java; scripting is being ported mostly to python.

Most programs are in	/usr/local/bin
Preferences are in	/usr/local/observatory/prefs
Various status files are in	/usr/local/observatory/status
Data on crux is in (while observing)	/home/observer/data/tonight

(otherwise) /home/observer/data/YYMMDD
where the date is of the night of observation.

A copy is stored on mtkent1 at /data1/cdk20s/YYMMDD
and is backed up on mtkent2 at Mt Kent Observatory and mtkent3 and mtkent4 at University of
Louisville's Moore Observatory.

Main Programs

xephem Written by Elwood Downey, this program provides a zoomable sky view, an extensive object database, markers for telescope and target position, and much more. See <http://www.clearskyinstitute.com/xephem/help/xephem.html> for the reference manual.

xmtel Provides a GUI for controlling the telescope.

xmccd Provides a GUI for controlling the primary camera.

ds9 From the Smithsonian Astrophysical Observatory (SAO), this GUI provides viewing and some analysis of fits image files produced by xmccd.

domeshow.sh Shows the current dome azimuth.

dometrack.py Moves the dome to match the current telescope azimuth.

getfocus Gets the current focus position in encoder counts.

setfocus Changes the focus position by a number of pixels

plotfocus.py Plots the FWHM, amplitude, and focus value for a selected star in a series of ds9 images, to aid in focussing

solve-field-cdk20 Run on mtkent1, this script performs astrometry on an image using the astrometry.net code (<http://astrometry.net/>). It reports back the J2000 coordinates of the centre of the image, and generates an image with WCS coordinates included (as filename.new).

solve-field-fast-cdk20 Is faster if the auxilliary images are not wanted.

imdark etc A suite of programs to perform elementary operations on fits image files, ie dark subtraction (ls /usr/local/bin/im*)

astrocc Nominally a coordinate converter, but can also search for targets, provide times and airmass.

astroimagej A powerful GUI run on mtkent1 for performing relative aperture photometry on images. It is based on ImageJ (<http://rsbweb.nih.gov/ij/>) and Göttingen ImageJ Resources (<http://www.astro.physik.uni-goettingen.de/~hessman/ImageJ/>). See <http://www.astro.louisville.edu/software/astroimagej/>. AstroImageJ can provide live plotting of the results of photometry on a series of images.

gphoto2, eog Nikon image fetch and view.

session_start.sh

observatory_start.sh

session_stop.sh

observatory_stop.sh

These scripts are the preferred way of starting and stopping an observing session, and handle powering up the hardware and opening the shutters, setting up data directories, running background processes, and starting up the various GUIs for controlling the hardware.

look_east.sh, look_west.sh These are used to choose the appropriate scripts for scripted tracking (discussed later), which depends on whether the telescope is pointed east or west of the local meridian.

temphumid_get.py Read the telescope temperature and humidity.

Support Programs

These are infrequently used programs/scripts, or are run in the background.

indiserver This server program is run in the background, and communicates directly with the mount and primary camera via drivers. xephem, xmtel, xmccd then talk to indiserver to control the hardware. The hardware settings can be seen or changed from the indipanel GUI, which can be opened by a menu item from xephem's skyview window.

indiget, indiset These command line programs can be used to access the hardware settings in indiserver, and are useful in scripting.

dome_monitor.py This program runs in the background and reads the dome RFID tags as they pass, writing the current tag value to a file.

dome_azimuth_change.py Moves the dome

shutter_open, shutter_close Controls the shutters ?????

update_tonight.sh Sets up the cron system process to check every two minutes for any file changes in the crux directory /home/observer/data/tonight, and update the corresponding directory /data1/cdk20s/data/tonight.

ccd_monitor.sh

ccd_process.py

guide.py These scripts facilitate keeping a selected star on the same ds9 pixels over hours, and also keep the dome aligned with the telescope.

Starting an observing session

Now (and frequently thereafter) is a good time to check the weather. See the “Checking the weather” section. There is weather checking software in place/being developed, but it is also important to do your own monitoring. Please don’t open up when the weather is dubious (it is easy to get absorbed in observing etc and miss that damaging shower) or when the humidity is above 95% (and be checking regularly for condensation when above 90%). Also it is generally inadvisable to open the shutters between sunrise and sunset unless certain that direct sunlight cannot reach the telescope mirrors.

If not already released, the two dome lockdown fasteners must be released, and the two lockdown catches between the upper and lower shutter also released. The covers over the telescope apertures must be removed. It is also a good idea to check that chairs etc are clear of the telescope space against the dome wall.

The telescope must be in the “top-dead-centre” position before the mount is powered, that is, pointing to the south celestial pole with the telescope “above” the mount. If necessary, power up the mount and use the hand controller, or do the following:

1. In one window run “indiserver tel”
2. In another window run xmtel, and select the slew checkbox (not the button)
3. Using the dome camera zoomed in, align the marks (on white background) using the *NSEW* buttons in xmtel
4. Remember to power the mount off (so that its encoders are reset on startup).

Change the filterwheel name (read by xmccd on startup). The filterwheel names are in *.ccd files in /usr/local/observatory/prefs. Copy the appropriate file to prefs.ccd in the same directory.

Now run session_start.sh, and wait for it to finish. This will power up all except the dome and dome light, start xephem, xmtel, xmccd and ds9 as well as background programs, and set up the tonight data directories on crux and mtkent1.

Next run observatory_start.sh, and wait for it to finish. This will power the dome and the dome light, and open the shutters (you did check the weather, right?)

There are a couple of operations that the scripts cannot perform.

1. From the top of the small xephem GUI pull down the *View* menu and select *SkyView*. This will open a sky view window.
2. From the top of this new window, pull down the *Telescope* menu and select *INDI panel*. This will open an Indiserver panel window.
3. At the bottom of this new window, click on the *Connect* button. This will show icons for *tel* and *ccd* which can be expanded (click on +) to see the various parameters. In the panel above will appear messages about changes to the mount and camera.
4. The camera temperature has been preset to -10C. If a different value is desired, this can be changed from the xmccd *Set* menu

Note that it takes time for the camera temperature to stabilize (~30m) and for the dome and telescope to equilibrate (up to an hour).

It doesn’t hurt to open a log.txt file in the tonight directory on crux (/home/observer/data/tonight), to record details of the night’s observations. A simple text editor on crux is nedit.

Lastly, move the telescope from pointing to the south celestial pole to the desired side (east or west). Check movement in the dome camera at <http://domecam.mko.usq.edu.au> . Ensure that the slew checkbox near the top of xmtel is selected. If intending to look east for example, use the xmtel W

button to move the telescope body ~20 degrees. The telescope (not the weights) should move towards you in the camera. Then use the N button to move the telescope northwards. In the camera this should show the telescope pointing higher in the sky. In xephem's skyview window, the telescope marker should move from the south celestial pole northwards in the eastern (left) side of the sky.

Routine procedures

Checking the weather

The **number one responsibility** after operating the telescope is to ensure **both shutters are properly closed**.

The **number two** responsibility is to **check the weather** before opening up and regularly during an observing run. An automatic closing system is being installed, but it is best to regard this as a backup.

The weather instruments can be accessed at: <http://orion.mko.usq.edu.au/cgi-bin/Davis2Html.cgi>. Of particular interest is the Boltwood Cloud Detector, which has a field of view of ~90 degrees and looks a bit west of the zenith. Readings more positive than ~-30C indicate some cloud present, and caution should be exercised. The Boltwood will also detect the presence of rain, responding faster than the Davis weather station.

A backup cloud detector and rain detectors have been installed and will be available soon. How to access ???

An all sky camera is available at <http://skycam.mko.usq.edu.au> (username *root* with password #3) as a further check on cloud. To save heavy bandwidth usage, get a snapshot by going to <http://moondog.astro.louisville.edu/remote/video/index.html> and pressing the *Southern Night Sky* button.

Syncing the mount

This procedure provides a way of ensuring very accurate pointing (target typically ends up dead centre in the image on first go), using the astrometry.net software. It currently must be repeated after moving from the east to west part of the sky or vice versa.

1. Slew the telescope with xmtel (with the *NSEW* buttons, or enter coordinates in the target boxes then click the slew button) to the target or a suitable mid-altitude point. (Don't go within 10 degrees of the pole or the local meridian.)
2. Set the *Basename* as in the xmcdd *Fits* menu, the exposure time to 10s from the *Set* menu, and a midrange filter from the *Filter* menu.
3. Take an exposure with the *Expose* button. (Download will take ~20s)
4. Astrometry works best with a dark-subtracted and focussed image. If the image isn't sharp, focus as described later.
5. Select *Dark* from xmcdd's *Type* dropdown menu. Then take a dark frame with the *Expose* button. (Remember to change *Type* back to *Light*)
6. Change directory on crux to /home/observer/data/tonight.
7. Make a dark-subtracted image with the command line "imdark testnnnnn.fits dark_mmmmm.fits testnnnnnd.fits" where nnnnn etc refers to the appropriate image serial numbers.
8. Now move the dark-subtracted image testnnnnnd.fits to mtkent1 with the command line "scp testnnnnnd.fits mtkent1:/home/observer/data/junk"
9. Log in as observer on mtkent1, and change directory to /home/observer/data/junk
10. Run the command "solve-field-fast-cdk20 testnnnnnd.fits and wait for the coordinates of the centre of the solved field to be given. (If this takes more than a couple of minutes, Ctl-c to exit, point the telescope elsewhere, and repeat). These coordinates are for epoch J2000.
11. Now convert these J2000 coordinates to Equinox of Date (EOD) coordinates. On the xephem root GUI, pulldown the *Tools* menu and select *Coordinates Converter*. In the top left box enter EOD. In the second line, paste the RA and Dec produced from the astrometry (J2000 coordinates). The converter will then produce the equivalent EOD coordinates in the first line. Paste these into the *Target* boxes of xmtel.

12. Finally, to sync the mount, in xmtel pulldown the *Reference* menu and select *Target*, then pulldown the *Pointing* menu and select *Offset*. If the *Guide* checkbox at the top left of xmtel is selected, and the mount is nudged with one click on one of the *NSEW* buttons, the *Telescope* boxes should be seen to match the *Target* boxes. The software has offset its internal RA and Dec variables to match where the telescope is pointing as determined by astrometry.

Crossing the local meridian (E->W or W->E)

The telescope should not be slewed across the local meridian (line from N to S passing directly overhead). Instead follow this procedure.

1. In xmtel, turn off the pointing correction by pulling down the *Pointing* menu and deselecting *Offset*.
2. Move the telescope to dec ~-85S (either by the S button, or by entering -85 in the *Target* Dec box then clicking the Slew button).
3. Turn the dome light on, and use the dome camera to view the telescope.
4. With the *Slew* checkbox for speed selected, press and hold the *Slew* button, until the telescope has moved well past the dec = -90 position. (This can be seen in the camera on the white tape markers on the dec axis).
5. The RA can now be slewed through the top-dead-centre position ie moving the telescope across the local meridian. If the telescope is to now point east, use the E button (the telescope should move towards the dome camera). If the telescope is to now point west, use the W button (the telescope should move away from the dome camera).
6. Check in xephem's SkyView window that the telescope marker is on the desired side of the meridian.
7. Remember to adjust ds9's image rotate/flip for the different side of the meridian, as follows.
For the telescope:
 - pointing E, pull down the *Zoom* menu and select *InvertY*. (All other transforms off)
 - pointing W, pull down the *Zoom* menu and select *InvertX*. (All other transforms off)

Slewing to a target

Slewing to a target can be as simple as entering Equinox of Date (EOD or Now) coordinates into xmtel's *Target* boxes and pressing the *Slew* button. Once the target is reached, the mount starts tracking with the motor encoders only (good for a few tens of seconds exposure). A "Goto complete" will briefly appear in the xmtel message window. (Alternatively the message can be seen in the message section of the Indipanel window). If the telescope has been synced and EOD coordinates were entered, the target should appear in the centre of the field.

To convert J2000 coordinates to EOD, see #11 of "Syncing the Mount". Alternatively start up astrocc (EOD coordinates are produced in the bottom section.)

For longer exposures (typically 20-100s, perhaps to 300s), the high-res encoders should be used, by clicking the xmtel *Guiding* button. To keep the target on the same pixels over longer periods (to many hours), see the "Scripted Guiding" section.

To stop the mount click xmtel's *Stop* button. This also stops tracking and guiding.

Note that xmtel will not slew within ~10 degrees of the horizon, or far across the local meridian (see "Crossing the local meridian").

Note too that xephem does not automatically update the time it is using – press the *Update* button for this. (If forgotten, RA and Dec are of course unaffected but Azimuth and Altitude are.)

The *Target* boxes of xmtel can also be filled by right-clicking on an object in xephem's SkyView window, and selecting *Telescope GoTo* (doesn't work for planets). Alternatively, a target can be searched for by name using xephem's *Data* menu. From this select *Index*, and a search window opens. Make sure the *All* checkbox is checked. The search box is fussy ("M31" not "m 31" but "NGC 5866"; it also helps to put a * wildcard on the end). At the bottom of the window, the *SkyPoint* button will mark the target in the SkyView window and the *Telescope GoTo* button will load the coordinates into xmtel's *Target* boxes.

If a desired target is not found, other catalogs can be included by pulling down the *Data* menu then selecting *Files*. In the resulting new window select again the *Files* menu and select from the offered catalogs (described in following table, together with number of objects).

General clusters, nebulae, galaxies			
NGC.edb	7,955	Revised New General Catalog (2005)	
IC.edb	5,201	Revised Index Catalog (2005 -NGC supplement)	
Messier.edb	110	Messier Objects Catalog (2005)	
SAC.edb	1,887	Saguaro Astro Club (2002)	
ovocc.edb	1,599	Optically Visible Open Clusters Catalog (2002)	Our galaxy
DeepSky-C.edb	326	Deep Sky Objects Common Names (2003)	
pleiades.edb	442	Pleiades field membership (1995)	
Galaxies etc			
HYPERLEDA.edb	101,767	HYPERLEDA Catalog (2003 Part 1 – Bright)	Bright
HYPERLEDA_dim.edb	881,495	HYPERLEDA Catalog (2003 Part 2 - Dim)	Brighter than 18B mag
UGC.edb	7,331	Uppsala General Catalog	Bright Galaxies (from Palomar Sky Survey)
cgcg.edb	29,363	Galaxies and Clusters of Galaxies Catalog (Zwicky)	Galaxies & clusters of galaxies
Abell.edb	5,250	Catalog of Rich Clusters of Galaxies (1989)	Clusters of galaxies
Hickson.edb	563	Hickson Objects Catalog (1994)	Compact clusters of galaxies
qagn.edb	64,866	Quasars & Active Galactic Nucleii (2003)	
Nebulae etc			
lbn.edb	1,125	Lynd's Bright Nebulae (1965)	Dec N to ~30S
ldn.edb	1,791	Lynd's Dark Nebulae (1962)	Dec N to ~30S
Barnard.edb	349	Barnard's Catalog of Dark Objects (1927)	Milky Way
DCld.edb	1,101	Catalog of Dark Southern Clouds (1986)	South of 33S
cgsr.edb	231	Catalog of Galactic Supernova Remnants (2001)	
sh2.edb	314	Sharpless HII Regions (1959)	Dec N to 27S
hh.edb	454	Herbig-Haro Objects	Star formation
Stars			
Hiptyc2.xe2	2,538,127	Hipparcos & Tycho-2 Catalogs	
bs.edb	5,953	Bright Star Catalog	
YBS.edb		Yale Bright Stars Catalog	
Starsnav.edb	173	Nautical Almanac Navigation	
SKY2k65.edb	8,882	SKY2000 (Bright subset)	Above M6.5
SKY2000	299,167	SKY2000 Master Catalog (2002)	Above M8
hd.edb	272,150	Henry Draper Catalog and Extension (1924)	~complete to M9
hde.edb	88,883	Henry Draper Extension Charts, (1995)	Fainter magnitudes

Pulkovo.edb	58,483	Pulkovo Pul-3 Catalog	Astrometric, proper motions
XZ80Q.edb	244,269	XZ Catalog of Zodiacal Stars (2003)	
ppm.xe2 468586	468,586	Positions and Proper Motions Catalog	
Stars: doubles, variables, etc			
gcvs.edb	31,852	General Catalog of Variable Stars	
aavso.edb	28,435	AAVSO Stars Catalog	Variables
WDSC.edb	98,186	Washington Visual Double Star Catalog (2005)	
CCDM.edb	105,838	CCDM-Components of Double and Multiple Stars	
COVBS.edb	1,832	Sixth Catalog of Orbits of Visual Binary Stars	Orbits of Visual Binaries
SSC.edb	2,872	Sternberg Supernova Catalogue (2004)	
pulsars.edb	559	Princeton Pulsars Catalog (1993)	
Calibration/Photometry			
loneos.edb	33,860	LONEOS Photometry Catalog (2003)	
CPIRSS.edb	37,700	USNO IR Stellar Sources Catalog CPIRSS (1984)	
Zwicky.edb	19,368	The Updated Zwicky Catalog (1999)	Galaxies
sstar_calib.edb	1,179	WDS Single Star Calibration Catalog (2004)	
constant.edb	34	Catalog of Constant Brightness Stars (1997)	Constant Brightness Stars
vla*cm.edb	2,531	VLA Radio Calibrator Sources	
binary_calib.edb	81	WDS Binary Star Calibration List (2004)	

Note: The Guide Star Catalog (GSC) is built into xephem in a special compressed form which cannot be searched, but its stars are displayed. (They are called Field Stars. GSC2201 has 451,632,833 stars up to M18.5 and gsc has 18, 839,509 stars up to M15).

Alternatively Simbad (<http://simbad.u-strasbg.fr/simbad/sim-fid>) is a great way to search for an object by name and retrieve its coordinates.

Another great way to search xephem's catalogs, with very flexible search criteria, sorting capability and outputs selection, is at <http://orion.mko.usq.edu.au/cgi-bin/objects.cgi>. If you have a USQ login, we can allow you to also output the actual catalog data lines at <https://orion.mko.usq.edu.au/cgi-bin/objectsfull.cgi>. Help for these is available at the websites. For example, you can search for all objects in a selection of catalogs that will be within 5 degrees of a specified RA * Dec at 9pm tomorrow night.

Confirming “on target”

Ensure that rotate/flip in ds9 are set correctly for which side of the local meridian the image was taken (this ensures the image is displayed E-left N-up).

For the telescope:

- pointing E, pull down the *Zoom* menu and select *InvertY*. (All other transforms off)
- pointing W, pull down the *Zoom* menu and select *InvertX*. (All other transforms off)

Bring up an xephem SkyView image that matches the image taken with the primary camera:

1. Ensure SkyView is in equatorial (RA-Dec) mode (Axes button half way down the left toggles between this and Alt-Az) with E-left N-up (indicator at bottom right – otherwise use flip buttons on left).

2. Pull down SkyView's top left *Control* menu and select *Eyepieces* to bring up the eyepieces window. Click on the *Use* button to the left of the *Apogee* box to select a field of view matching the CDK20-Apogee camera field of view (FOV). Then close the eyepiece window.
3. Right click on the target and select *Center* to center the target, then drag the left slider near to the top to zoom nearly fully in.
4. Again right click on the target and select *Place Eyepiece*. A square box matching the camera FOV will appear centred on the target.

Now compare star distances, pair angles and brightness (allowing for different filters) to confirm the target position. Skyview star brightness can be adjusted with the “light bulb” buttons at the upper left.

Alternatively Aladin <http://aladin.u-strasbg.fr/java/alapre.pl> can be used to retrieve a real image for comparison.

For completely unambiguous target identification by its coordinates, astrometry can be used as in “Syncing the mount” but using “solve-field-cdk20 filename.fits”. This will produce an image named filename.out which has coordinates embedded. This image can then be displayed in ds9 on mtkent1, and moving the mouse over the image will display J2000 epoch coordinates for the mouse position. An annotated image can also be produced.

Moving the dome

To move the dome to align with the telescope, give the command “dome_track.py”. The command “dome_show.py” will show where the dome currently is. (Both commands rely on dome_monitor.py running in the background. This is started by the startup scripts). The dome will track to within 5 degrees. Note that dome_track.py runs once – it does not keep the dome tracking as the telescope is moved.

The command “dome_azimuth_change angle” will change the current dome azimuth by the signed angle in degrees.

Taking an image

From the xmccd GUI do the following if not already done:

1. Pull down the *Set* menu and set
 - a. The exposure time in seconds
 - b. The number of images to take if doing a multi-image exposure (*MultiFrame count*)
 - c. The sequence number to include in the filename, only if it needs changing (*Image number*)
 - d. *Image region* if a download of the full image is not required.
2. Pull down the *Fits* menu and set
 - a. The *Baseline* for the filename (remember to include an underscore after trailing numbers to distinguish the sequence number appended by xmccd). Xmccd automatically sets names for dark, bias and flat fields when these types of images are selected.
 - b. The name of the target (added to the fits header)
3. Pull down the *Filter* menu and select the filter (Names are filled in once the filter is selected). See “Starting an observing session” for changing the filterwheel ID. Currently this must be done before xmccd is started. The filter sets are:

UBVRI	RGB	GRIZ	Narrow
1 U	1 Clear (UV Block)	1 g'	1 SII
2 B	2 R	2 r'	2 Ha
3 V	3 G	3 i'	3 Red Continuum
4 R	4 B	4 z'	4 OIII
5 I	5 Open	5 BlueBlock (Exoplanet)	5 Clear (UV Block)
6 Open	6 Open	6 Open	6 Open

4. Pull down the *Mode* menu and select either *Single* frame or *Multi* frames.
5. Pull down the *Type* menu and select one of *Light*, *Dark*, *Bias*, *Flat*.
6. Pull down the *Processing* menu and
 - a. Tick *Transfer* if the image once downloaded is to be opened in ds9 automatically.
 - b. Tick *Scripting* if scripted tracking is desired. (See the “Scripted tracking” section.)

If the exposure is longer than ~10s, guiding with the high-res encoders is probably required. Press xmtel's *Guiding* button (it toggles guiding) if not already pressed and check the state in xmtel's message pane or in xephem's IndiPanel.

Now press xmccd's *Expose* button, and the *Exposure* indicator will count down the exposure seconds. It then takes about 20s for the image to download. When this is complete, the *Status* indicator will change to *Camera ready* and the *Filename* indicator will show the new filename. If automatic transfer is enabled (see 6a above) the new image will then be displayed in ds9.

An exposure can be interrupted with xmccd's *Interrupt* button

Viewing an image

Sao ds9 is a powerful astronomical image viewer. For user and reference manuals, a FAQ, and tutorials see <http://hea-www.harvard.edu/RD/ds9/site/Documentation.html>. The following are some useful introductory operations.

Note that the Magnifier (top right box) is a magnified subsection of the displayed part of the image, about the current mouse position, with the central cursor showing the mouse position and the size of one pixel. The Panner to the left represents the total image, with the box indicating what is shown in the main image window. The box in the Panner can be dragged to pan across the image.

From the **View** pulldown menu it is useful to tick *Horizontal Graph* and *Vertical Graph* in order to see cross-sections through objects as the mouse is moved. The *Min Max* and *Low High* options are also useful for seeing pixel extreme values.

The **Scale** button or menu gives choices for how brightness and contrast are transformed from the fits file data to the display. *Linear* is useful for seeing the image with just a linear transform. *Log* is useful for bringing out fainter detail of eg nebulae and galaxies and faint stars. In both cases, right clicking and dragging across the image in one direction changes brightness and in the other contrast. For more control, from the *Scale* pulldown menu select *Scale Parameters*, which opens a histogram window where the black and white levels in pixel counts can be set.

The **Zoom** button or menu allows zooming in/out.

To **orient the image** with the usual convention left-E up-N, it must be flipped depending on whether the telescope was looking east or west (characteristic of German Equatorial Mounts).

For the telescope:

- pointing E, pull down the *Zoom* menu and select *InvertY*. (All other transforms off)
- pointing W, pull down the *Zoom* menu and select *InvertX*. (All other transforms off)

With this convention,

- as the xmtel E button moves the telescope E, the star appears to move W in ds9.
- as the xmtel N button moves the telescope N, the star appears to move S in ds9.

In summary, with these settings, east is to the left and north is up, and the xmtel *NSEW* buttons move the telescope in the indicated directions (star in display moves in opposite direction).

A **Pixel Table** showing pixel values in a small region about the cursor can be generated by selecting *Pixel Table* under the *Analysis* menu. Size can be adjusted from its *Size* menu.

The **Fits Header** can be displayed by pulling down the *File* menu and selecting *Display Fits Header*.

The **Color** menu allows selecting the colormap and for example selecting black stars on a white background with the *Invert Colormap* option. The *Reset Colormap* sets contrast/bias to the default values.

By selecting **Preserve During Load** from the *File* menu, one can select individually whether the following are preserved during load of a new file

- Existing scale parameters
- Existing pan location
- Existing regions

The **Regions** menu allows drawing various shapes (circles, rectangles, lines, text etc) on the displayed image. These can be for annotation, or various forms of processing (eg for scripted tracking). If regions are not being used, they can be deleted with the *Delete All Regions*, and showing regions can be disabled by deselecting *Show* in the *Region Parameters* selection. Regions are drawn by click-and-drag on the image, and selected by clicking within the region. A selected region can be dragged, or resized by dragging over the handles. The *Get Region* selection on the *Regions* menu brings up a dialog box that allows read/write of the parameters of a selected region.

To find a **star's centroid**:

1. Region=>Region Parameters=>Centroid Parameters Set Radius to max (50)
2. Put a region round a star and leave it selected
3. On command line, do "xpaset -p ds9 regions centroid". This moves the region to the star's centroid.
4. Run "xpaset ds9 regions". This gets the region's properties, including the circle's (X,Y,R)

This can also be done from within ds9. Once the region is drawn and selected, do *Region=>Centroid* then *Region=>Get Information*

Dark subtracting

First take a dark image of the same exposure with xmccd by selecting *Dark* from the *Type* menu, then click the *Expose* button

This image will be called dark_mmmmm.fits, where mmmmm is the image serial number.

Now make a dark-subtracted image with the command line "imdark targetnnnnn.fits dark_mmmmm.fits targetnnnnnd.fits" where "target" is the target name, nnnnn refers to the image serial number. Notice the "d" after the second nnnnn, denoting the dark-subtracted image.

More sophisticated dark subtraction, using a median combined series of dark images, can be performed from within AstroImageJ. See "Introduction to AstroImageJ" section.

Bias frames (zero exposure time) can be taken by selecting *Bias* from xmccd's *Type* menu.

Focussing

The switch of the focuser control box must be on to *Comp* (for computer), and the Focuser/FinderScope turned on at the Ethernet Power Controller.

An exposure time of ~1s is convenient. Don't select a bright star for focussing as it may saturate quickly as focus is approached. Select *Guiding* on xmtel so that the star does not drift excessively.

Draw a circular region centred on the selected star, of large enough size so that the star won't drift outside (radius of ~200 suggested), and select it by clicking within. By clicking the *Region* button on xmccd, only the region will be downloaded, reducing download time greatly. To later restore xmccd to full download, deselect the region and click the *Region* button again. (Alternatively in xmccd *Set->ImageRegion->Off*)

The plotfocus.py program can be run to automatically Gaussian fit to a star and add its FWHM, peak amplitude (above background) and focus position to three plots. Help can be obtained with "plotfocus.py ?". A single circle region is required round the selected star, large enough so the star won't drift outside.

Alternatively FWHM and amplitude can be judged from the ds9 horizontal graph. Remember to work with linear scaling to correctly judge the half-maximum. The max of the horizontal graph is set by the high value set on the *Scale=>Scaling Parameters* window.

Now take a few images to get an idea of seeing variation.

The getfocus program displays the current position of the focuser in encoder counts. The command "setfocus x" will change the focus by ~x pixels in FWHM.

Scripted Guiding

These scripts facilitate taking a series of images over a number of hours while keeping a star on more or less the same pixels (required for millimagnitude photometry), and also adjusting the dome. It is really tuned for 100s images.

Certain background scripts must be running, which are started by the startup scripts.

Follow these steps:

1. Ensure the focus is at the desired setting, and the image is centered.
2. In ds9, pull down the *File* menu, select *Preserve During Load*, and tick all 3 items.
3. In ds9, pull down the *Region* menu, select *Region Parameters* then *Centroid Parameters*, and set *Iterations* to 30 and *Radius* to its max of 50.
4. In ds9, pull down the *Region* menu, select *Region Parameters* and tick *Show*.
5. In ds9, pull down the *Region* menu, select *Shape* and select *Circle*.
6. Orient the image with the usual convention left-E up-N
For the telescope:
 - pointing E, pull down the *Zoom* menu and select *InvertY*. (All other transforms off).
 - pointing W, pull down the *Zoom* menu and select *InvertX*. (All other transforms off).
7. In xmccd, pull down the *Mode* menu and select *Single* (for single image).
8. In xmccd, pull down the *Set* menu and set the *Exposure* to 100s.
9. Ensure that other xmccd settings are correct (*Filter*, *Fits* etc).
10. Ensure in xmtel that *Guiding* is turned on.
11. Take an image. Ensure that you are happy with the positioning etc.
12. Depending on whether the telescope is looking east or west, run “look_east.sh” or “look_west.sh”.
13. In ds9, select a star to guide on (intermediate in brightness), zoom in, click on its centre and drag a circle region out. Select this region by clicking within it.
14. Set the color to red (*Region=>Color=>Red*) and radius to 50 (*Region=>Get Information=>Radius*)
15. Duplicate this region on top of itself by Ctl-c then Ctl-v. Move the cursor on top of the selected region (cursor changes to 4 arrows) then drag it aside. Change its colour to green, then move it back onto the red circle, leaving it (the green one) selected. (This region has to be big enough for the star to stay within it between two exposures (it get recentered) but small enough not to include other comparable stars)
16. In xmccd, pull down the *Processing* menu and tick *Scripting* (This will enable the scripted guiding once an exposure is taken)
17. When ready to begin exposures, click xmccd’s *Expose* button

An image is taken, and the star is located within the green circle, which is then centred on the star. The scripts then nudge the mount to try to position the star in the next image taken in the centre of the red circle. The dome position is adjusted, then another image is taken.

The process can/should be watched in the message pane of the *IndiPanel* (of xephem’s Skyview window: from Skyview *Telescope=>IndiPanel*).

The process can be stopped (losing the current image if being taken) by pressing xmccd’s *Interrupt* button, or after the next image by pulling down xmccd’s *Processing* menu and unticking *Scripting*.

Note that currently dome tracking will fail if the telescope crosses the meridian, and the mount stops tracking near the horizon or ~10 degrees after crossing the meridian.

Introduction to Live Aperture Photometry with AstroImageJ

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Changing the filterwheel

Have a clean plastic bag on hand to take the current filterwheel, and a blower to dust off the filters of the new wheel before installation. Also, transport the new filterwheel in its plastic bag.

1. It may help to orient the mount so there is easy access to the filterwheel housing.
2. Rotate the pull knob on the back (camera side) of the filterwheel housing counterclockwise until the filterwheel is free in its hub.

3. Undo the knurled knob on the side of the housing and carefully lower the side door, being ready to hold the filterwheel on its body, not on the filters.
4. Carefully slide the filterwheel out and place it in the plastic bag.
5. Remove the new filterwheel from its bag and dust the filters both sides with the blower, again being careful not to touch the filters.
6. Face the writing on the filterwheel towards the telescope, and slide it in to the housing, holding it in place.
7. Close the side door and do up its knurled knob.
8. Carefully rotate the pull knob (on back) clockwise and feel the filterwheel being located on its hub. Only do up light finger tight.
9. Power up the filterwheel via the Ethernet Power Controller and the switch on the hand controller (mounted on the sloping side of the plinth). Press the home button on the controller and confirm in its display that the home is successful and the first filter position is reached.
10. Carefully store the old filter (labelled) in the control room of the EDG building.

Finishing up

1. Allow two minutes for the background process to copy any new files from crux to mtkent1.
2. Drive the dome so the dome azimuth is ~0, as given by the domeshow.sh command. This ensures the solar panel charging the shutter battery gets full sun. Alignment marks can be checked with the dome camera zoomed in and pointing just to the right of the dome.
3. Drive the mount to the home position. Use the dome camera to see the marks on the white tape on each axis, and use xmtel's *NSEW* buttons with *Slew* selected.
4. Give the command "observatory_stop.sh". This turns off dome power and closes the shutters. Once this has finished, **check that the shutters are fully closed with the dome camera**.
5. Give the command "session_stop.sh", and wait till finished. This powers down all else, exits the various programs, and renames the tonight directories to YYYYMMDD. You may have to rename the tonight directory on mtkent1:/data1/cdk20s to YYYYMMDD
6. Save and close any log file, and exit the various xterm windows, and log out.
7. If at the observatory and it is required, engage the two dome lockdown turnbuckles, and the two shutter latches, and return the mirror covers to the telescope.
8. **Very important!!!** Double check that the shutters are closed, the dome is parked, and the dome door locked.

Downloading data over the net is a slow process – if on site you may want to copy the night's data to a portable drive. The images are ~64MByte each.

Troubleshooting

Xephem

On SkyView->Telescope->Configure

Check: Enable sending RA/Dec go	with tel.target_2000.ra tel.target_2000.dec
Check: Enable Sky marker from	with tel.telescope_2000.ra tel.telescope_2000.dec

Coords given for object are J2000 (if Equinox set to 2000 in xephem main window (under Local heading))

Is crux time correct?

Make sure crux's time is correct. Can run /usr/sbin/ntpq -p to check the ntp daemon.

To restart the daemon, as root type

cd /etc/rc.d

./ntp restart

Dome

dome_monitor.py reads tags and writes

ID => /usr/local/observatory/status/dometag

azimuth => " /domeazimuth

dome_show.sh reads domeazimuth file and displays it

tel_show.sh ditto for telescope (RA & Dec)

dome_track.py Reads tel coords and dome azimuth, works out which way to move, and moves dome to right place (once)

Behind autosending to mtkent1 (set up by the startup scripts)

On crux in /home/observer/data

1. Make directory YYYYMMDD for tonight's data
2. Make a symbolic link to "tonight's" dir ie 20120917, by "ln -s 20120917 tonight". (20120917 can now be referred to as tonight)
3. Run "crontab -e". This will start editing observer's crontab file (using vi by default, can change with EDITOR environment variable)
4. Insert the following two lines (or remove '#' from start of second line if already there)
Update tonights images every 2 minutes
0-59/2 * * * * /home/observer/bin/update_tonight.sh
5. Exit (For vi, Esc to leave edit, then ZZ to exit). This will now run "update_tonight.sh" every 2 minutes, storing (for example) the 20120917 directory's contents in /data1/cdk20s/tonight on mtkent1

At end of night:

1. Stop the cron job by inserting a '#' char before the 0-59 in the crontab file, by running "crontab -e" as before (i when in vi gets you into edit mode, Esc to exit edit mode, ZZ to exit)
2. Run "rm tonight" on crux in ~/data directory to remove the symbolic link
3. Rename tonight on mtkent1 to the nights directory eg "mv tonight 20120917" (in /data1/cdk20s

update_tonight.sh (the crontab job) contains (all one line)
rsync --progress -L -ave ssh /home/observer/data/tonight
observer@mtkent1.mko.usq.edu.au:/data1/cdk20s/

Focusser

The last position is stored in (owned by observer)
/user/local/observatory/status/telfocus a text file
getfocus reads this file

Startup & Shutdown

session_start.sh

Kills any running observatory programs
cd to /home/observer/data
Creates yyyyymmdd directory
Removes tonight
Soft links tonight to yyyyymmdd directory
Copies all /home/observer/data/queues files to tonight
Removes any observer crontabs
Starts the crontab to update mtkent1 with the files in tonight (every 2 minutes)
Powers up needed hardware (commented out for now)
Start indiserver
Start ccd_monitor.sh Handles autoguiding if enabled
Starts xmtel, xephem, xmccd
Sets some INDI parameters
Sets ds9 preferences

session_restart.sh

Restarts user programs (assumed killed) but not indiserver

session_stop.sh

Reverse of above

observatory_start.sh

powers up observatory stuff (not camera) and opens dome shutter

observatory_stop.sh

Reverses above

