The semi-official manual for the JGT

Overview

The James Gregory Telescope, short JGT, is the largest telescope in Scotland. With a maximum aperture of 37”, it could even be called the largest operating optical telescope in the United Kingdom, if we are a little bit generous. The JGT is the centerpiece of the University Observatory in St Andrews, located at the edge of town surrounded by green sports fields. Since its inauguration in 1962 it has observed a wide range of astronomical objects and has been used by several generations of researchers and students. The JGT is a unique telescope, with the largest Schmidt-Cassegrain optics in the world, a bespoke electrical and mechanical system, and many anomalies that are only partially understood. To my knowledge, this is the first attempt to write down a comprehensive description of the telescope. So far, the knowledge about the telescope is largely stored in the minds of the current staff, the notes left behind by previous staff, as well as in several boxes of beautiful and detailed mechanical and electrical drawings. It seems desirable to transfer at least some aspects of this knowledge into a more permanent, coherent and accessible format. This is the purpose of this book.

This book is a living document and is likely to be updated as the JGT and our knowledge about it evolves. It describes the JGT primarily as it is and not how it became what it is. For more insights into the history of the JGT I highly recommend [Stars over St Andrews](), by Ron Hilditch. The chapters are sorted in groups, which are primarily aimed at observers, engineers, and administrators. For the purposes of this book I assume that the JGT is a research telescope, as it currently is, used by astronomers. That’s why I include instructions for actual observing. If the JGT at some stages become something else, a visitor attraction or a museums exhibit, some of this information might become useless.

I am indebted to Roger Stapleton, the JGT expert in St Andrews, who has not only kept the telescope alive for a considerable time, but is also largely responsible for its development over the last decade (his notes are a treasure chest for JGT enthusiasts and are online as well). He has made the JGT fit for the 21st century. Without the knowledge gained in many conversations with Roger, over countless cups of coffee, this manual would never have happened. If it ever happens.

Aleks Scholz, Observatory Director, 2018.

Content

All chapters with a version number 1.0 or higher are in relatively good shape.

Observing with the JGT

With the help of these documents, astronomers should be able to teach themselves how to observe with the current configuration of the JGT.

Inside the JGT

These chapters are probably most useful for people who want to repair the JGT or build around the JGT. They are also recommended for observers who want to learn more their telescope.

The JGT administration

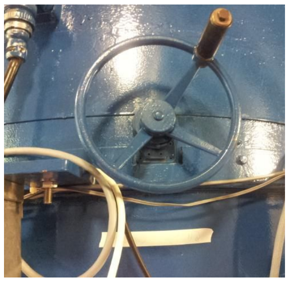
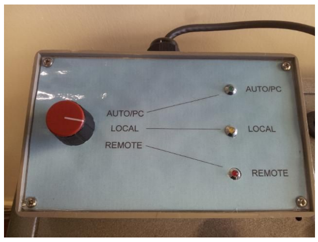
The following chapters are most useful for anyone who is involved in the adminstration and the management of the JGT. They cover the current operation, the support, and the future plans.

Startup and shutdown

This is the basic step-by-step guide to getting the whole thing started and shut down - the bare minimum needed for observing with the JGT. It is also the document that changes most frequently and hopefully it will be regularly updated to reflect all changes. The hardcopy version in the dome is probably constantly outdated. Current version of this document: May 2018

Startup procedure

1. **Go into downstairs control room** ('Lumsden Room'). Log into the control machine (the iMac) as observer. You should get a screen with three shells on the left side and possibly some other windows. Switch on the second wall-mounted screen.	
2. Start CCD camera and cool it down - either Andor or SX Trius. See camera section for details.	
3. Log in to telescope computer with the black window: 'ssh -Y quadrans'. Start control program: './control' - move the window to the wall-mounted screen.	
4. Open a new page in the logbook, which should be next to the control machine.Note date, name, weather, time, camera, observing plan.	
5. **Go to upstairs machine room** (the little room in the corner of the dome). Open the power cabinet at the far end. Switch on the 24V (white switch) and the 440V (central green lever) power supplies.	
6. **Go into dome.** Have a look around and check that nothing is in the way. In particular, the red rails of the platform should be lowered, the ladder of the platform should be down, no cables on the floor, and the platform disconnected from the base of the telescope.	

7. **Open the dome.** Climb the ladder at the south side of the telescope, take the cable on your right out of the rope loop, and plug it into the right socket on the dome - the yellow marks should line up. Push the switch to 'open' position and hold it until the dome is all the way open and the motor stops. Then detach the cable and secure it in the rope loop.	
8. Open primary mirror cover by turning the handle on the northwest side of the telescope.	
9. Turn mains power for backend on - it is the upper left socket on the northeast side of the telescope. You might have to climb the platform to reach that switch.	
10. **Go back to machine room.** Switch on screen in the far corner. Log into the telescope computer as observer, open terminal, and start the program that displays the telescope position: './display_pos'.	
11. Turn around and face the control panel - the large grey metal box with lots of knobs. Switch on the screen above the control panel. It should now also show the telescope position.	
12. Check that the selector on top of the console is on 'AUTO/PC' (and not 'LOCAL' as shown in the picture or 'REMOTE').	
13. Switch on the tracking with the red button on the left side of the console. Wait until you hear the characterisic low-pitch drone from the dome, indicating that the telescope is tracking.	

14. Slew the telescope to target using the two large dials on the console. The further the dial is turned, the faster the telescope moves. Move first in DEC (right dial) towards the south. Always move the knobs gently and watch the telescope while it moves.	
15. Move the dome with the buttons in the lower left corner of the console, so that it approximately is aligned with the telescope. This will be exactly aligned by the computer later on.	
16. Open the telescope cover using the remote mounted at the window in the machine room. **Attention:** The telescope and its optics is now fully exposed to the outer elements. From now on, don’t lose track of the weather conditions outside and close the cover quickly if it starts raining.	
16. Switch off the lights in the dome, go down, check the weather again, and go into the **Lumsden room**.	
17. Start the dome tracking in the control program. Switch to ‘on-screen’ with the button in the lower left corner of the control program.	
18. Take the test image with 5 seconds exposure time and check it.	
21. Adjust telescope positions with the NESW arrow buttons in the telescope control program.	
22. In the CCD program, choose root name for images, set exposure time and (possibly) filter. Then start taking science frames. Do not forget making notes in the logbook.	

Shutdown procedure

1. Start warm-up of CCD (see camera section). Switch off dome tracking.
2. Go upstairs. Close telescope cover with the white remote.
3. Park telescope with the dials at the console (parallel to polar axis DEC=80, pointing north HA=0).
4. Park dome with the console buttons in the lower left corner. Look for black marking.

6. Close mirror cover, switch off mains at the side of the telescope.
7. Close dome. (Be extra careful while doing that.)
8. Turn off power -24V and 440V in the power cabinet in the machine room.
9. Close display program on the telescope computer. Switch off screens.
9. Switch off lights in the dome and go downstairs.
10. Close camera connection and send iMac to sleep. Go home.

The cameras

The James Gregory Telescope can currently operate with three different CCD cameras. Each has a different purpose, and each requires separate observing instructions. The following should be read in conjuction with the document on the startup/shutdown.

	Andor	SX	QSI
Type	Andor DV434	Trius SX56	QSI5xx
Pixel size	13 mu	7.4 mu	9 mu
Field of view	16’ x 16’	48’x32’	
Max QE	52%	94%	77%

Andor

This 1Kx1K CCD is used for applications that require high quantum efficiency and high stability, typically for high-precision photometry. It has a field of view of about 16’x16’. The camera is operated from the computer that rides on the side of the telescope, but that machine can be fully operated from the terminal on the control computer (the iMac) in the Lumsden room on the ground floor. The CCD control program is a simple shell affair, which reacts to text-based commands.

The startup works like this:

- Connect to the machine upstairs: ssh observer@obsccd2, login with the usual password
- Start the image display program: ./ds9
- Start the CCD program: ./run_ccd
- Set temperature by typing ‘d’ and then ‘-50’.
- Switch on cooler with ‘f’.

Observing usually requires the following commands:

- To set the required filter, use ‘w’ - although it is likely that the Andor camera will only have one filter for the forseeable future.
- To set the exposure time, use ‘t’.
- To set the root of the filename, type ‘i’.
- Then set the initial number of the filename to 1, using ‘j’.
- Take one or multiple images using ‘a’.

The exit command ‘z’ also does a controlled warmup.

Note: The Andor camera used to be operated with relay lenses and a full filter wheel, behind the primary mirror. This setup was active for more than a decade and generated tons of data. In 2018 we switched to a system where cameras are mounted in the actual focal plane, which gives us access to a larger field of view. Whenever the manual references a filter wheel or relay lenses, this is probably outdated.

SX

The Trius is a camera that was donated to us by Space Insight Ltd for the purpose of space debris surveying. It is a wide-field camera and covers about 48’x32’. It is currently operated from the Windows computer in the machine room, but will hopefully have a direct link to the Mac in the control room soon. Here is how it work right now. We assume that the observer is sitting in front of the Mac.

- Connect to the autoguider machine via Remote Desktop (red icon).
- Create new directory for this night in the Desktop directory ‘Trius’. The convention here is to have a subdirectory for each year, and another one for each date.
- Start the program Nebulosity, a graphical software to operate CCDs
- Select ‘Starlight Xpress USB’ in the camera menu on the right. There is hopefully no error message.
- Click ‘Advanced’, switch to 2x2 binning, switch to ‘Enable TEC’ and set temperature to -30. Click ‘Done’. This will start the cooling process.
- Wait a few minutes for the camera to cool down. During that time, the telescope can be put in the right position.
- Take a bias series: Choose duration 0.0, exposures 10, name bias, then ‘capture series’
- Take dome flats, this should probably be done during daytime: rotate the dome until the slit is at 18 hours (in the control program, in the dome itself that position is marked ‘6’), leave telescope in parking position (HA 0, DEC 80), avoid direct sunlight in the dome, take a test image with 5sec, then adjust to get 25000 counts, name flat, exposures 10, ‘capture series’. Done.
- For shutting down: Choose ‘Advanced’ and set the temperature to 0. Then click ‘done’. From that point it will take again a few minutes for the CCD to warm up.

QSI

The QSI is a compact chip with an inbuilt filter wheel, that is good for multi-filter photometry with a limited field of view. It is operated in exactly the same way as the SX Trius, except that there is also a choice of filters.

The advanced observer

The startup and shutdown sequence is really just the beginning. It might be sufficient to get the machinery running and to take first images. It will be useful as a reminder after face-to-face training is finished. The information provided in this document is the next level. We are now going to assume that the observer knows where the computers and components of the telescope are and is familiar with the startup and shutdown routine. This is expert JGT-ing.

The JGT philosophy

The JGT is not a particularly simple telescope. It has an unusual optical design (an old-fashioned Schmidt Cassegrain), a unique mount, a rather intricate electrical system and lots of complexity in the computer system architecture. Most of these aspects are hidden to the observer. What the observer does experience is the complicated observing procedure. One might ask: Why can't I simply switch the telescope on and then just start taking images? Why more than twenty steps in the startup sequence, and not just one?

Here is the answer, or at least part of it. The JGT is a telescope with an old core and a modern outfit. This is partly by design, partly be necessity. In general, we try to maintain the old core as much as possible, while gradually adding digital technology. As a result, the JGT has become a layered telescope. Operating it is a journey through history. Originally it was built for use with photographic plates, and in principle, if we had spare plates, we could still use it this way. It's all still there. Now of course we use CCD cameras. The optics, mechanics, and most of the electrics are still original. The control panel is original. Around it sprouts a computer system that makes it feel almost like a modern telescope. But the observer operates some of the old mechanisms as well. Opening the mirror cover: old. Switching on dome tracking: new. Slewing the telescope to a target: old. Autoguiding: new (relatively speaking).

Nobody will say that the JGT is the most efficient or the most convenient telescope. But it is a beautiful combination of old and new that doesn't exist anywhere else in the world. We would like to keep it that way.

A talking telescope

The JGT is an ideal telescope for learning how to observe. One reason: It talks back, sometimes loud and obnoxiously. Most steps in the startup sequence elicit a reaction, either a sound or a light or something else. The telescope will tell you what's going on and it will tell you when things go wrong, and it's important to pay attention. With most other telescopes, the only way to interact with the technology is through a keyboard and a mouse. The JGT can be heard and felt and smelled. Make use of it. Here a brief and incomplete introduction to the language of the JGT.

When switching on the green lever in the power cabinet, the 440V source, there will hopefully be a uniform background noise, which should always be there when observing. The tracking motor causes a low-pitch droning sound. When opening the mirror cover with the old handle, you get to hear the gears turning, until you feel that the end has been reached. The motor that opens the dome makes a churning noise that stops when the dome is open. Often there is additional squeaking from the chains that connect the two sides of the dome slit. The dome rotation motor is very loud and bumpy. When moving the dome, you can feel the vibrations, particularly when standing on the platform. When slewing the telescope, the observer can hear the noises of the motor. They are not always exactly the same and depend slightly on the position of the telescope. When doing minor adjustments to the telescope, the smaller motors kick into action. Even from the warm control room downstairs, the RA motor can be heard - it is the same as the tracking motor. In contrast, the DEC motor for slow motion is very quiet. The autoguider creates its own sound universe with beeps whenever an image is taken, followed by adjustments to the telescope position.

The autoguider

Speaking of. The autoguider is a little black box mounted at the back end of the guider telescope (see picture below). It's the one that sits on the east side of the telescope and is just as long as the JGT. The autoguider box says 'SBIG' on its side. Here is a concise summary of how to use the autoguider, but there is an entire chapter on it for more curious minds.

If the observer needs the autoguider, the following two steps have to be done during the startup, before moving the telescope (because they can only be done easily when the telescope is in parking position): 1) Open the lid by turning a small blue wheel near the bottom of the guider telescope tube. 2) Switch the autoguider on, with a tiny switch at the back of the black box. A red light should come on, if it doesn't, perhaps the power isn't on. The autoguider is powered by the mains outlet on the south side of the telescope.

The autoguider is then operated by a Windows machine in the machine room, the second from the far end. This computer should always be on. If not, pushing the button at the front will boot it. To connect the control computer downstairs to the autoguider machine, use the rdesktop software on the control computer downstairs - a red icon in the menu.. This software opens a window which shows a link to the autoguider computer. Clicking on that link establishes a remote connection, i.e. the Windows screen will appear on the Mac. Once the screen is visible, login as observer and double click the icon that looks like a bullseye. Then attempt to start guiding with the obvious button in the lower right corner. The guider needs a fairly bright (V<10) star located in the southeast corner of the CCD field-of-view, and if it can't find any, it will just say so and abort. If it does find a star, it will immediately start guiding. At this point the observer needs to give the autoguider control over the telescope. There is a radio button in the lower left corner of the telescope control program that does just that. After that if one listens carefully you can hear that the motors at the telescope switch briefly on after every autoguider exposure and adjust the telescope position. That is a sweet sound and tells the observer that the system is working, the star is still there, and the telescope is on target.

The autoguider is quite useful to monitor the sky conditions. Once a bright star is selected and the system is guiding, it provides information about the peak intensity. By monitoring that value, the observer knows pretty much what the sky at the target position is doing and whether or not clouds pass through. If the autoguider loses the star, it stops guiding and gives out an error message. This does not necessarily mean that the guiding should be aborted - if it is just a small cloud passing through the guider will recover the star after a few minutes - but it is probably a good idea to check the sky the old-fashioned way in these instances, i.e. by going outside.

Beyond the control panel

The telescope can be moved at three different speeds. The dials on the control panel operate two big motors for the fastest speed. That's still not particularly fast. It takes a couple of minutes to slew the telescope from one side of the sky to the other. Still, it's worth watching the telescope when slewing, in particular the cables hanging from the back of the telescope and the counterweights. Nothing should ever hit anything, and cables should stay untangled, under normal circumstances. But if something looks weird or makes weird noises, it's a good idea to stop slewing and check. Even more important: Always switch the lights in the dome on before slewing. And: Always move the knobs gently. Always treat the telescope gently. Always watch for the feedback.

The first thing that happens when the dials are used is actually the opening of clamps that hold the telescope in place. The opening of the clamps is a loud, sharp noise. At the same time, there is the clicking of a relay from the power cabinet. All this is normal. Once the clamps are open, the telescope starts moving. When moving the dial back to zero, the clamps close again and the telescope stops.

With slewing the telescope can be brought within a few arcminutes of its destination. Smaller steps are done in slow motion. The two slow motions are called guiding and setting, and they are done with two extra motors, one in DEC, one in RA. The RA slow motion motor doubles as the tracking motor. Guiding speed is useful for adjusting the telescope position, setting is really not much used. In most circumstances, the fine adjustments will be done from the telescope computer with the control software. The only way to do this without the computer is using the handset (see picture, which also contains Roger Stapleton's finger). Most observers will never use the handset. That's what the computer is for, after all.

DEC centering

The slow motor in DEC - the one that does the fine adjustments, not the slewing - can only go for a specific distance (about a couple of degrees maybe?). If it is used more in one direction than in the other, it might reach its limit at some point during the night. There is a button on the control panel that recenters the drive. It is the one highlighted in the image. It is usually a good idea to push this button at the beginning of the night, before observing. If not, it can be done at any point later. When pushing the button, the motor will start to move for a few seconds and the button will light up. When it is finished, the motor will stop and the light will go off. One little interesting feature: There is a tiny chance that the telescope is far enough from centre for the light to go on, but not far enough for the motor to move. In that case the telescope will be blocked without actually doing anything. The only solution is to switch off the 24V, the white switch in the power cabinet, wait a few seconds, then switch it back on. This should clear the situation. But to be fair this is a relatively exotic snag.

The computer system

Most of the JGT operation is controlled by two computers, the CCD computer 'obsccd2' and the telescope computer 'quadrans', both are Linux boxes. Quadrans sits at the far end of the machine room, with its screen and its keyboard. Obsccd2 is permanently attached to the side of the telescope and linked to the Andor CCD with a thick grey cable. Its screen, keyboard and mouse, however, are also in the machine room. These two machines are also connected - quadrans provides the telescope coordinates RA and DEC to obsccd2, so that they can be written into the header of the CCD images.

There are two more computers in the machine room: Between the screen of quadrans and the screen of obsccd2 is the autoguider machine called obs-greg-1 - see above the notes on the autoguider. And the machine on the floor close to the door is another Linux box named fornax, a dedicated analysis and storage machine that observer might not need. It runs a rather arcane pipeline for lightcurve production and has access to all the CCD images. It also makes a backup during the day (as do two other machines, one in the Napier building, one in the School of Physics & Astronomy). Fornax also can be used with the observer login.

All four machines can be accessed from the downstairs control computer, which is currently an iMac. New cameras will be operated directly from this Mac, via an USB link. For the Linux machines, the easiest way to work on them remotely is with 'ssh -Y'. The autoguider machine is accessed with a tool called rdesktop. It is also possible to operate everything from the upstairs machine room, like in the old days. The observer can login to obsccd2, quadrans, obs-greg-1, and fornax with the observer account, and then run everything while sitting directly in front of the machines. This is useful to know - in case something is wrong with the remote access, there is always a fallback option.

The CCD control software and the telescope control software are coded and maintained by Roger Stapleton, who also maintains online manuals.

Quick note on focusing

Until 2018, focusing was done with the little brown box that should be found somewhere near the control computer downstairs. Usually focusing means that the detector is moved back and forth to find the focal plane, and since 2018 this is what happens. Until then things were slightly different. There were two extra lenses between camera and focal plane, and one of them can be moved with a little motor. This is what the brown box is operating. The focusing motor is located in the hole of the primary mirror, where the focal plane is located. Nowadays though focusing has become an afterthought - each camera has a pre-defined focus, which is adjusted with the mechanical dial at the back end of the telescope.

The limit switches

Sometimes the telescope stops moving on its own. This should never happen, if the observer watches the telescope and keeps it pointing at the sky, without getting too close to the mount. At extreme positions, hardware limit switches (hopefully) kick in and everything grinds to a halt. At the control panel, one of the limit switch lights will go on. These lights are all above the dials in a row, have a look at the picture. If one of these lights goes on, it is important to find out what the problem is by looking carefully at the telescope. Is it almost horizontal? Is it close to the pillar, the one that points north? Is the cable wrapped around the mount? Pushing the button that is illuminated should move the telescope back to safety. After that the observer can move it back to a more normal position with the slewing dials.

In addition to the hardware switches, which can only be seen in the machine room upstairs, the telescope control software also puts out warnings if the telescope comes too close to the horizon or is rotated too far around its pillar. The software does not stop the telescope though. The observer needs to take action. In any case, it is a good idea to monitor elevation and hour angle of the telescope when observing and to have a feel for the position of the telescope at all times. The JGT model in the control room downstairs is a great help for that.

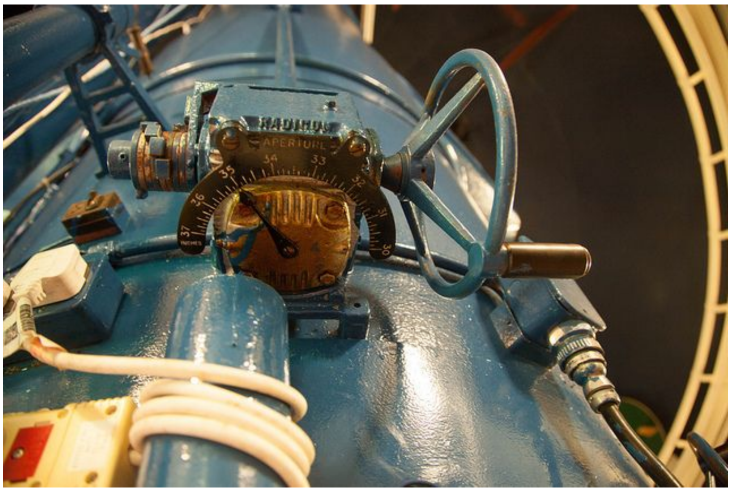
Sometimes, rarely, the limit switches go off in an entirely normal position. If that happens the telescope cannot be moved and some trickery is needed. A good course of action would be to close the dome, stop observing, leave a note in the logbook, go home and figure things out the next day.

Things not to touch

Not necessarily complete list of things the observer should never touch.

- The power lever for the mains electricity, on the right side at the bottom of the power cabinet. This provides power, among other things, to the CCD computer, which should always be on.
- The handle under the scale with numbers from 30 to 37 on the south side of the telescope (see picture). This adjusts a ring within the tube and thus changes the aperture of the telescope. It should stand at a position between 32 and 36 inches.
- All additional buttons in the autoguider software (those that do not just start the guider).
- The platform in the dome.
- Everything in the base of the telescope, behind the little steel doors.

Picture: The handle that controls the true aperture of the telescope, here set to 35 inches. This is why the statement ‘the JGT is a 37 inch telescope’ is misleading - we usually do not operate it at full aperture because it makes nicer images if the light that goes through the outer ring of the corrector lens is not used.



Recurring issues and some troubleshooting

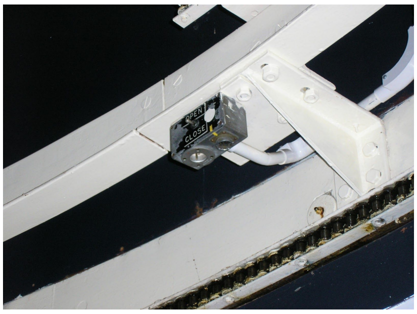
In general, failures are one of the most effective ways to learn something about the JGT. Observers will invariably encounter technical issues, if they just observe long enough. Some problems are like flies, although they come up every now and then, they don't cause much harm. Here are some examples. If something like that happens, leave a note in the logbook and move on. If something unusual happens that is NOT in this list, we want to know everything about it. The general rule is: If in doubt what to do about a problem, leave a note, shut down and go home.

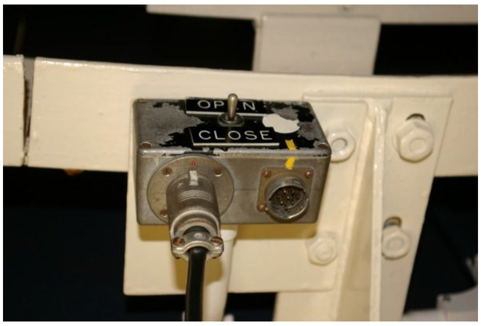
- With the Andor camera, sometimes bright stars seem to have trails. That could be either a tracking issue, but if it occurs in very short exposures (just a few seconds) and if the trails run over the entire image, it's a known CCD problem. We cannot solve it, but it doesn't seem to cause trouble so far.
- If the trails get longer with longer exposure time, it's probably an issue with the tracking. The tracking wheel is slippery in places, and sometimes the motor is not quite well behaved. If the tracking fails consistently, observing is probably impossible and it's time to go home.
- A couple of times every winter the dome gets stuck. This happens under excruciatingly loud noises and is therefore always a bit of a shock. Usually when that happens the dome is pointing northwest. Keep calm. Stop the dome. Then try to move it backwards, away from the block. Avoid that dome position for the rest of the night.
- If anything goes wrong with the filter wheel in the old Andor setup, a hardware reset often solves the issue. The observer would notice a problem in the CCD software - the program would report some failure to move the filter. Go upstairs to the machine room. The filter box is standing on the left of the telescope computer. It has six buttons with LEDs, one for each filter. Next to it is a red reset button. Push that button. The filter wheel should move back to filter number 1. Then try again operating it from the CCD software.
- Computer issues can often be solved by rebooting. In case one of the machines gets stuck, the observer can try a clean reboot, using the 'shutdown' option on the screen. We don't recommend doing a hardware reboot using the buttons on the computer itself. It might sometimes be necessary, but we would rather do it doing daytime.

The emergency shutdown

Situation: There is a power failure, i.e. no computer, no internet, no observations. The green LED emergency lights in the dome will still be on. Under these circumstances, the telescope can be left where it was, but make sure to switch the tracking off to prevent the telescope from wandering if the power comes back on. The dome, however, must be closed with an emergency routine which is outlined below. Most observers will never encounter this, but if you do, please be extra careful. It's a good idea to print out these pages and have them with you when observing. It is also a good idea to read the risk assessment for the JGT before observing.

In case of emergencies, call either 999 or 01334-47-6161.

1. **Find the battery box.** The black emergency battery box should be in the NW corner of the dome. The charger should be plugged in. A thick black cable should be on the shelf on the trolley next to it in the corner.	
2. Unplug the charger from the battery box. The plug has a locking tab that you need to squeeze to get it to unplug.	
3. **Find the shutter socket.** Look for the socket which you usually use to plug in the dome open/close power cable. Since you were observing, the socket could be anywhere around the dome.	

4. If necessary, move a ladder to the socket. The one between telescope and machine room is the largest, but it is slightly difficult to get out.	
5. **Connect the battery.** Move the battery and the thick black cable to a place close to the shutter socket.	
6. Take the cable up the steps with you and plug the socket end into the box on the dome - in the outlet NOT labelled with the yellow marker (the left one). The plug will only go in one way round.	
7. Plug the other end of the cable (the one with the blue ring) into the battery box. Again it will only go in one way round. Screw on the blue ring.	
8. **Close the dome.** Switch the battery to ON with the toggle switch on the box. The dome should close now.	
9. When the dome has stopped, switch the battery OFF.	
10. **Tidy up.** Disconnect the black thick cable. Put the battery and cable back where you found them. Plug in the battery charger. Put a note into the logbook. Go home.	

Risk assessment for JGT observing

Observing at the JGT happens naturally at night, and often without supervision by staff. As a result, specific safety measures are in place. All observers at the JGT are required to familiarise themselves with the potential hazards before working with the telescope.

People at risk

All observers at the JGT, i.e. trained PG students/postdocs/staff, Honours UG students, some visiting observers (especially exposed are lone observers). An extra risk assessment is available for visitors during open nights.

Potential hazards

- *Equipment failure:* Occurs frequently, but rarely causes any hazards. If unexpected failures happen, shut down the telescope (minimum: close the dome), write a report in the logbook, and leave. Instructions for regular shutdown and emergency shutdown in case of power failure are part of the regular observing training and are summarised in the JGT documentation.

- *Falling from height:* A realistic hazard is falling from the steps when opening/closing the dome. Never climb higher than necessary, and always switch on the light before opening/closing the dome. The platform in the dome and the observing balcony should not be used during the observations at all.

- *Injuries while operating the telescope:* No history in the past years, but a possible risk (e.g., falls in the dark, falling from the steps when opening/closing the dome). Always carry a torch when walking through the building or switch on the light, especially when using the stairs. Strictly follow the provided instructions when handling the telescope. Do not experiment at night time, instead shut down if in doubt. For minor injuries, a first aid kit is available in the machine room next to the dome. In case of major accidents, call for help (see below). For lone observers, make sure that someone knows that you are at the telescope.

- *Intruders from the outside:* No known cases, but some traffic over the playing fields happens from time to time. Simple solution is to always close and lock the door when inside the building.

- *Fire emergencies:* The electrical system in the Gregory building is old and a recent case of cable fire proves that this is possible. If you notice a fire and you are not trained in the use of fire extinguishers, leave the building and call for help (see below).

- *Major injuries/sickness while operating the telescope:* If unable to shut down the telescope, call for help (see below). For lone observers, make sure that someone knows that you are at the telescope.

How to call for help

Aleks' cellphone: 07399 682839 (don’t hesitate to call that number)
Out of hours emergency number of the University: 01334 47 6161
Emergency number: 999

Put these numbers in the contact list of your phone before observing.

Short safety rules for lone observers

- Always inform someone else from the JGT team (another observer or Aleks) that you are at the telescope in a given night AND that you got back safely (e.g., by sending a short email or a text message).

- Bring a torch, a cellphone, and warm clothing.

- Document your observing night in the logbook in the control room.

- Familiarise yourself with the safety rules and wiith the location of the first aid kit.

- Close and lock the door when observing.

- Never move in the dark without torch. Switch the light on, if necessary.

- If in doubt about a technical problem, shut down.

The backend

Introduction

Mounted at the backend of the telescope are most of the systems the observer will operate during the night, the CCD camera, the computer running the camera, possibly the filter wheel, the focusing mechanism. The backend is currently changing, that means, all following information might be in flux. In short, we are currently moving cameras to the focal plane, which should simplify the setup and leave less to explain.

The CCD cameras

The JGT can be operated with various CCD cameras, which are described elsewhere. For many years, the only CCD was an Andor DV343, which was mounted behind the primary mirror with a filter wheel. That means, it was also behind the focal plane, and the images had to be relayed using a system of two simple lenses. This convoluted setup is currently being phased out. Instead, we aim to mount cameras in the focusing tube in the hole of the primary mirror, on camera holders that imitate a photographic plate holder, using as much of the original mechanism as possible. That way, the cameras will sit in the original focal plane and can be taken out within minutes. The downside is the space limit in the focusing tube - only about 7 inch in diameter are fully available. The cameras at the backend need various cables - the Andor is operated through a thick grey cable with bulky connector, while USB cameras are ran through USB plus power cable.

Shutter, filter, focus

In the current setup, there is limited space for filters. Cameras are provided with a filter holder that takes 50mm broadband filters - but only one at a time. The filter is held in place by little tabs. Only the QSI camera comes with its own little filter wheel. The Andor camera needs an external shutter. We are using a Melles Griot 04 UTS 201 shutter which is operated via another cable that connects to the backend. For focusing, we use the mechanical focusing wheel, which moves the tube up and down. Each camera requires a slightly different focus, but the focus is very stable.

For work at the backend, we use specific tools which are all stored in a drawer at the back of the machine room. One key aspect to consider when working on the backend is the balance of the telescope. When taking parts off weight has to be added to one of the tabs around the primary mirror. A few kilograms can make a difference to the stability of the telescope. Ten kilograms or more out of balance can mean disaster.

Historic notes

As mentioned above, the Andor camera was operated with a filter wheel - a heavy black flat box between CCD and the bottom of the tube. The filter wheel contains 6 openings, each with a 50mm filter, including standard BVRI broadband filters and VR narrowband filters. The filters are rotated by a motor which can be seen in the picture as cylindrical black box. The filter wheel also contains a shutter. Shutter and filter are linked to a big-ish box at the backend of the telescope, between camera and computer. From there, cables run to the CCD computer. Ultimately the shutter and filter wheel are operated from the same program that runs the CCD.

The JGT control system

Introduction

The control system allows the observer to move the telescope. It entails the motors and gears, the power cabinet and control panel in the machine room, and all the electrics and mechanics in between. The observer will typically only see the control panel (or the few parts that are still in use) and the screen of the control software on the telescope control computer (quadrans). The whole system is driven by two different circuits, the normal mains and the 24V DC. The latter runs most of the core controls system. (In addition, the 440V three phase powers the dome and platform.) This document is probably the least reliable and least complete - the JGT control system is not simple.

Motors

There are two motors for movement in right ascension, i.e. around the polar axis, and two for movement in declination, i.e. around the DEC axis. The polar axis is the axis that points towards the polar star, towards the north wall and at an angle of 56 degrees with the floor. The DEC axis is perpendicular to that and horizontal. For each axis one of the motors is big and used for fast slewing, although the JGT really never moves very fast. Two smaller motors, one for each axis, are used for fine adjustments. The two DEC motors are both visible in the dome, the big one is right at the DEC axis, the little one on the eastern arm of the fork that holds the telescope (see picture). The two RA motors are inside the base of the telescope. The smaller RA motor doubles as a tracking motor - fine adjustments in RA are made by speeding up the tracking or reversing it.

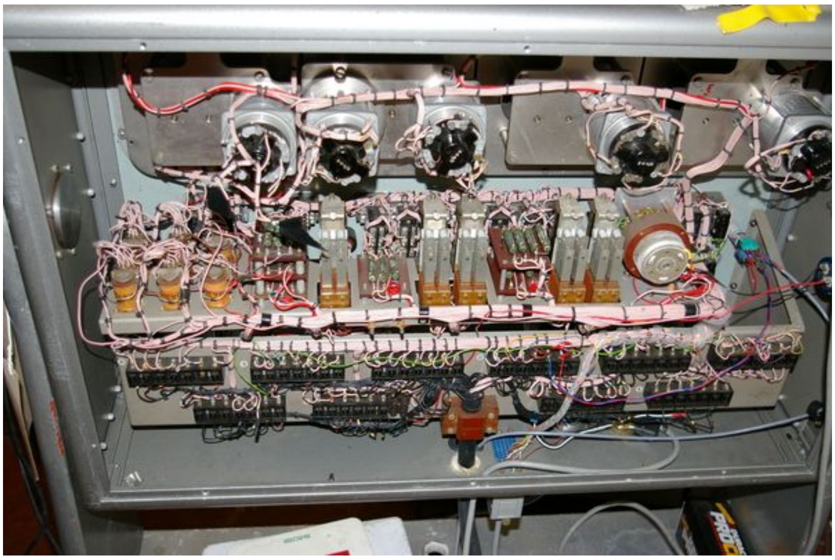
The big motors include gearboxes, magnetic clutches, and mechanical clamps (only on the DEC axis) that hold the telescope in place when the motors are not used. The clamps are disengaged before the motor starts moving, which causes the characteristic sharp noise. The motors are controlled by 24V servo circuits, the signal provided by a potentiometer at the control panel. The amplitude and polarity of the input signal determines the speed of the drive. The movement of the telescope drives another set of servos as a feedback loop, which was used to display the position of the telescope and is used to read off the position with encoders. The JGT's pointing model, if that term is allowed to use, is part of the hardware.

The smaller DEC motor is coupled to a tangent arm on the DEC axis and can only move the telescope by a specific distance (defined by the length of the tangent arm). This motor can only be operated from the handset and the software, not from the main panel.

Control panel

The original control panel at the JGT is still in use - the observer needs it for slewing the telescope, for switching on the tracking, and for monitoring limit switches. Two buttons in the lower left corner control the dome motor. The two dials for slewing operate potentiometers. Using one of these dials initiates complex circuit wizardry which a) opens the clamp, b) connects the drive, and c) actually drives the telescope.

At the top of the control panel is a series of limit switches. Those stop the telescope when it goes below 5 degrees from horizon, beyond 400 degrees around the polar axis, beyond the limits of mechanical movement in DEC. The limit switches de-activate the system and illuminate the corresponding switch. The system can be brought back by pushing the switch. If for some reason the telescope travels beyond the limits defined above, there is a second series of cut-out switches that deactivates the system entirely. If that happens (which means there has to be a failure in the first series of switches), the telescope has to be brought back to life manually. The horizon limit switch of the JGT is operated by gravity, at least in theory - a weight in the east fork would fall down when the telescope approaches a horizontal position, triggering the switch. In practise, this does not seem to work in the intended manner. The weight does fall down occasionally, but not quite when it’s supposed to do so.



The position display on the control panel is linked to the dials inside the telescope by ‘magslips’ which need to be calibrated using a star at a known position. This has not been done for a long time; the display is not accurate anymore.

The control panel looks very simple from the outside, but inside it is a mess. This is a view after taking off the back plate, only to demonstrate how much ‘stuff’ is hidden.

The fine motion

The system to adjust the position of the telescope accurately has gotten rather convoluted over the years, but for good reasons. The general idea is, as always, that the old telescope is still intact, and all new components are planted on top of the old one, using functionality that is already there.

It starts either with a handset or with something that imitates a handset, and it ends with the motors, in DEC or RA. The motor in RA is a stepper motor and also doubles for tracking, the fine motion simply changes the tracking speed. The motors are controlled by relays located in the power cabinet in the machine room - that’s the click the observer hears when using the fine motion. The motors understand two different speeds, SET (slightly faster) and GUIDE (really slow). For the RA motor, these speeds correspond to +/-200% or +/-20% of the tracking speed. Two handsets are available, one in the dome at the platform (REMOTE) - that one needs to be plugged into the telescope - and one in the machine room (LOCAL). A box at the top of the control panel has a three way switch that decides which option is active (meaning, which one is powered): handset LOCAL, handset REMOTE, or AUTO/PC. PC stands for computer control, AUTO for autoguider. Only in AUTO/PC setting can the telescope be moved by the computer or the autoguider. In the following we discuss this setting a bit more in detail.

The control computer and the autoguider essentially imitate the functions of the handset, but they do this in two different ways. The control software has buttons for the four cardinal directions, and a switch for SET and GUIDE speed. These buttons operate a set of relays located in a box that sits on the bottom of the control panel. (As a sidenote, the lines from the handsets are also routed through this box.) The autoguider on the other hand sends its signals via the line that comes from the REMOTE handset. It essentially pretends to be the REMOTE handset. (Therefore, it can also be used when the three-way switch is on REMOTE).

In the control software, the user also toggles between control via computer and control via autoguider. If the computer is on control, then the buttons with the cardinal directions etc. are active and the system is controlled via the relays box at the bottom of the control panel. If the users chooses autoguider, then an additional relay in the same box switches the control to the REMOTE handset. That way, the autoguider can get permission to operate the telescope through the telescope control system.

Control software

The control software itself is a C/C++ code written by Roger Stapleton, running on quadrans. It knows the position of the telescope from the encoders in the base of the telescope. It also knows the position of the dome from the RFID readers. It can translate the telescope position into a desired dome position via a mathematical model. With that, the software does the automatic dome movement to track the motion of the telescope, if the user decides to switch that on. The software can also move the dome and operate the fine motion of the telescope. The program writes out the position of the telescope into a text file, from which it can be retrieved for example, by a camera software.

The core of the software is a loop that reads input and reacts to events. Those events could be: the dome is too far away from the needed position, the user pushes a button, or whatever else Roger has taken into account.

We also have a smaller piece of code that can display the telescope position without any interactive functions. This code just reads the coordinates from the aforementioned text file and shows it in an interface. Therefore, it only works when the main control software is already running. It allows us to operate the main software remotely, and still see the telescope position on the local screens.

Historic notes

We have an old master layout of the electrical circuit of the control system as it was planned, which contains several differences to what was actually implemented.

In the lower left corner it appears that the 24V (and another 50V) was generated from the three phase via transformers. This is no longer the case. For most of its existence, the 24V came from a battery that was charged from mains and located in the electrical cupboard on the ground floor. Only around 2012 was this battery replaced by a 24V source directly from mains and the current switch in the power cabinet was installed.

The diagram shows variable speed gear boxes in three different places - on the DEC axis for slewing and fine motion and on the polar axis for slewing. This was apparently the initial idea, fixed speed motors plus variable speed gears. It would have allowed to move the fine motion in DEC with variable speed. The telescope only has one variable gear box, next to the polar axis motor, but that one is disabled. Variable speed motors are installed everywhere, except for the fine motion in DEC.

The gravity limit switches were supposed to be realised as Mercury switches. That did not happen, instead we have weights falling around which do not really work.

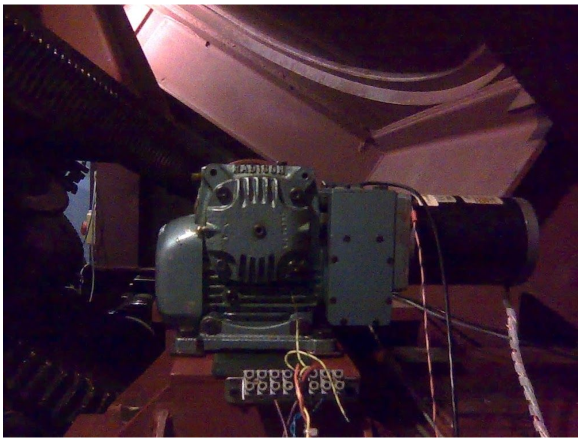
The sidereal drive was not implemented in the way it is shown. The diagram shows a unit that generates a frequency and drives a sychronous motor, but that seems to be detached from the diurnal drive turns the worm gear. In reality the two clocks on the ground floor (not shown in the diagram) provided a pulse that was used to regulate the speed of the Uhrgan drive (also not shown here). (This entire paragraph is not really clear.)

Sidereal tracking

Introduction

Astronomical telescopes need to be capable of following the motions of the stars. At the JGT (and in many other older systems) this is achieved by pointing one axis of the mount towards the celestial north pole and by rotating the telescope slowly around that axis. This is called sidereal tracking. Sidereal tracking is always imperfect - the pre-determined speed of the sidereal tracking, the geometrical setup of the telescope, as well as the mechanics of the drive determine the accuracy of the tracking. Flaws in the tracking are usually adjusted by the guiding - the autoguiding system of the JGT does that if a suitable guide star is available. Tracking and guiding together aim to keep the star always at the same spot on the detector, which has notable benefits for the accuracy of brightness measurements.

Current JGT setup



The telescope is mounted on an equatorial fork mount, with an equatorial axis tilted to point to the celestial north pole, and a declination axis. The sidereal tracking around the equatorial axis is achieved through a stepper motor that operates a worm drive, which translates the motion onto a gigantic gear wheel which sits on the polar axis of the telescope. The picture shows the motor, with the big gear wheel on the left, the worm hidden behind the motor, all on the east side in the base of the telescope.

If the system is tracking, the big wheel would make one full revolution in a sidereal day. One revolution of the worm gear will move the big wheel by one teeth. The big wheel has 576 teeth, which translates to a worm period of 150 sidereal seconds or 149.6 seconds. Of course we do not want the wheel to turn by 24 hours because it would wrap all the cables around the mount of the telescope - there is a limit switch that stops the sidereal drive from doing so, but it is currently not implemented. This motor also doubles as motor for fine-adjustments to the right ascension as part of the telescope control system.

The motor is controlled from the sidereal drive unit - a white box located right next to it, in front of the east side window of the base of the telescope. This box contains primarily the motor controller and a little Arduino computer that sends pulses to the drive, based on various inputs. The box has been built and is maintained by Mark Ross from the electronics workshop in the School. The box has one output line (to the motor) and four input lines: mains power (but attention, this is 110V!), 24V DC, an USB link for remote control, and a cable that contains four lines from the control system: forwards backwards, in SET or GUIDE speed. These four lines come via multiple relais from the control computer and can also be operated by the handsets - see the chapter about the control system for more details. The unit itself is started by a switch on the outside of the box, but that switch should always be on. The power to the unit is controlled from the tracking button at the control panel - the red one on the left side.

By default, the sidereal drive runs at uniform speed, hopefully exactly so that stars are stars and not stripes. With the buttons of the control system, the speed can be increased or decreased by 200% or by 20%. The first is the SET speed in the control program, the second the GUIDE speed. At SET speed, the drive can therefore be made to go backwards. Technically, we can also run the drive at 100% reduced speed - by switching it off.

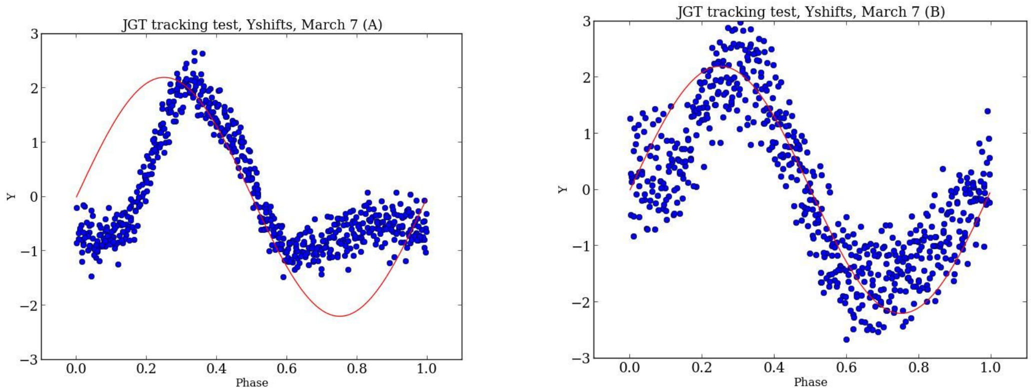
The remote control is achieved by sending serial commands through the USB link to the Arduino. The first option there is to switch on the lookup table, designed to cancel out the drunken worm (see below). The command for that is LOOKUP and thus rather intuitive. To go back to default speed the Arduino listens to the command NOLOOKUP. Furthermore, the observer can control the speed manually, by sending PC followed by a number. That number represents a factor that can be set anywhere between 0 and 7. Floating point numbers are allowed. The maximum prevents the motor from making awful noises. This serial link is currently still in its infancy - desirable is a software that can send these commands in a comfortable way from our control computer. This feature should make it possible to adjust the tracking speed to follow objects that move relative to stars, think asteroids or space debris.

There is a backup unit for sidereal tracking that sits right behind the active unit and is fully functional. It takes the same input, but doesn't have the option for remote control and only runs at one speed. This was the unit used until 2017. If there are issues with the active unit, the observer should be able to just move the cables across and then run from the backup system.

The drunken worm

The drunken worm is a periodic deviation from the average sidereal tracking speed, caused by an error in the slope of the worm drive that turns the telescope around the polar axis. This worm error can be easily measured by monitoring a bright star with short exposure times without guiding, and measuring the centroid of that star. The period of the worm error is the same as the worm period, the amplitude about 2 arcsec. The worm error was not discovered until the telescope was used without by-eye guiding in the 1990s. It effectively increases the seeing of the telescope by 1-2 arcseconds, if the exposure time is a significant fraction of the worm period, which may contribute to the excellent photometric accuracy that we typically obtain by smearing out the point spread function over more pixels, thus allowing longer exposure times and reducing flatfield errors. The worm error cannot be avoided through on-chip guiding, only through guiding on a bright star with exposure times of a few seconds. Since it should be predictable, it is desirable to cancel it out by periodically varying the speed of the drive.

Over the years a number of attempts have been undertaken to quantify the extent of the drunken worm with the aim to implement corrections. These are two plots from one of the most recent tests, which are document more in detail in the incomplete paper Through the Motions.

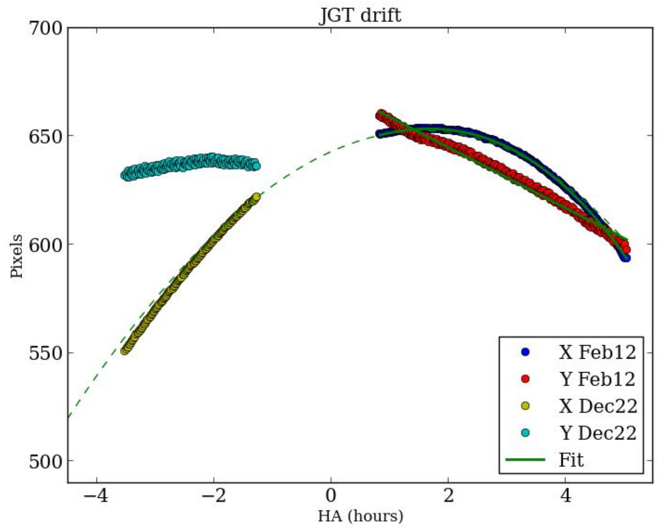


The plots are produced by taking lots of consecutive exposures of a bright star with exposure times much shorter than the worm period (2 sec), on March 7 2016. In each image, the pixel position of a bright star was measured. A period was fitted to the data and the datapoints plotted in phase to the period. The images for the left plot were taken early in the night when the field was close to the meridian (mean hour angle of 1.4). The images for the right plot were taken later when the field was setting (mean hour angle of 4.5). While the main worm error oscillation is clearly visible with a period of 149.6+/-0.2 sec, the tests also show that the shape of the oscillation seems to depend on hour angle. A sinusoidal variation fits the right hand plot well, with sub-pixel residuals that are comparable to the error. For the left hand plot, the subtraction of the same sine curve leaves systematic residuals. For all these tests the drift of the telescope on longer timescales (see below) was removed with a linear fit.

A simple solution for the worm error is to run the sidereal drive with a lookup table which contains a series of correction factors for the speed of the drive. As the drive is going through the worm cycle, it would correct the speed to cancel out the sinusoidal variation. This lookup table has been derived from the experiments described above and was tested in 2016 on the sidereal unit. It reduced the worm error by about half - the remainders is likely to be dependent on hour angle, but we have not tested this yet. It also remains unclear what the origin of the hour angle dependence is - could that be related to the weight distribution of the telescope? Or the specific properties of the teeth of the gear wheel? Robert Waland's notes from 1962 mention that the worm gear had 6 damaged teeth, which were carefully repaired until the resulting backlash was minimised. But maybe this is still causing a bit of discontinuity. More testing is needed.

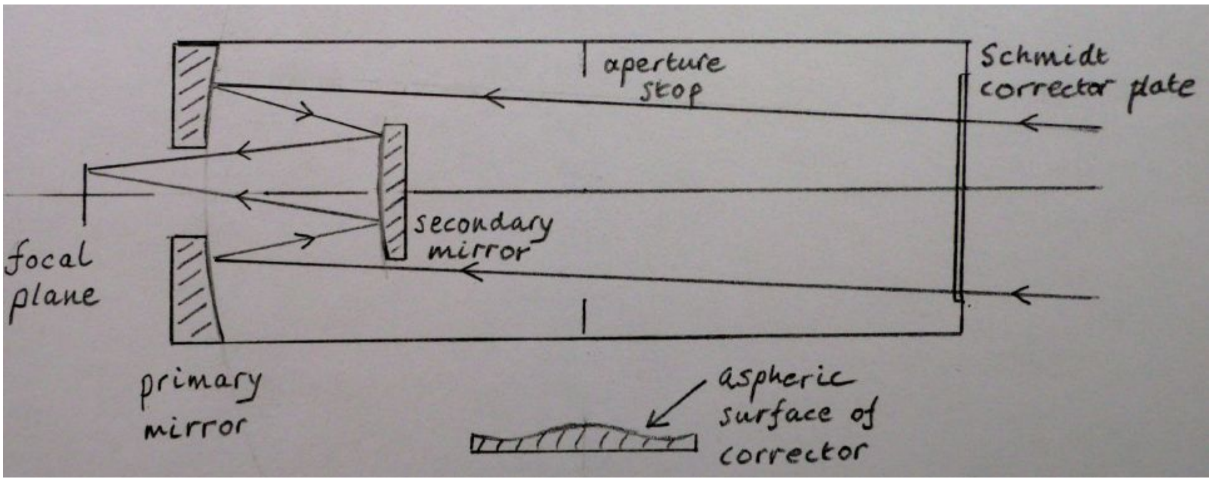
Sidereal drift

In addition to the short-term worm error, the telescope will slowly drift away from its original position, both in RA and DEC. The drift rate was measured in 2016 in a series of tests. The figure shows the results - note that this plots combines data from different runs and includes arbitrary shifts on the y-axis between runs. In declination, it is likely to be described with a quadratic function that reaches zero around hour angles of +2 and increases towards both sides of the sky. This might be best attributed to polar axis misalignment, i.e. a small offset between the polar axis direction and the northern celestial pole. In right ascension there is also slow drift that might also be best described by a quadratic equation - but over timescales of a couple of hours a linear fit seems sufficient. However, the right ascension drift sometimes shows a ‘wobble’ around the linear or quadratic trend, which could be related to issues with some of the teeth on the gear wheel. A run over the full range of hour angles is needed to determine the terms of the drift equations more accurately.



The optical system

The JGT is an f/3 optical telescope of Schmidt-Cassegrain design. The original optical path comprises two mirrors with spherical surfaces and a lens, the Schmidt corrector plate, which is flat on one side and aspherical on the other side, as illustrated below:



This design results, in theory, in an undistorted wide field of view, in the case of the JGT on the order of 4 by 4 degrees. The general idea of the Schmidt design is avoiding off-axis distortions like astigmatism and coma by using a spherical rather than a parabolical mirror, while cancelling out the spherical aberration with the corrector plate. The corrector plate is supposed to be located near the center of the curvature of the primary mirror. The JGT was one of the first Schmidt-Cassegrains ever constructed and remains to this day the largest optic of this type in the world.

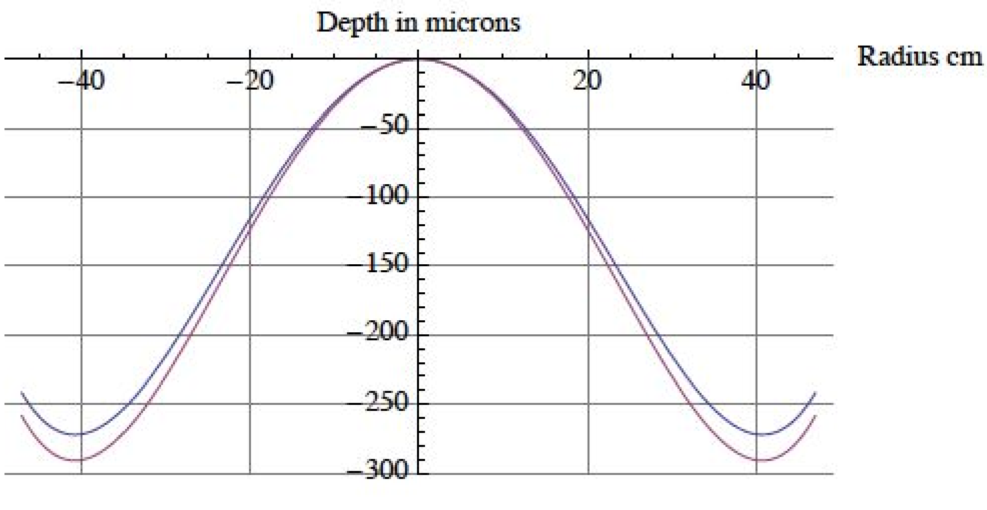
The JGT's corrector plate is 37" in diameter, the primary mirror 38.25", and the secondary 18.75". The hole of the primary mirror is 12" in diameter. The telescope has an aperture stop in the middle of the tube, that allows the users to adjust the diameter of the aperture between 30 and 37". The primary has a diameter to thickness ratio of 6:1 and a weight of about 250 kg. On the east side of the telescope, a guider telescope is mounted - an 8" refractor with a slow optics of about f/12.

It is worth noting that the exact measurements of the optical system, beyond the numbers quoted above, are not particularly well constrained. From recent communication with Ian van Breda (who worked as optical engineer on the telescope in the 1960s) we infer that the separation between primary/secondary mirror and aperture stop is 162.56/78.26 cm - this was before the correction described below. The curvature in primary/secondary is given as 295.78/283.77 cm. The separation between primary and secondary would be 84.3 cm. The distance between primary and corrector plate may be 337.8 cm. All these numbers should be taken with a grain of salt, although according to van Breda the dimensions and positions of the mirrors are probably okay.

The collimation of the secondary mirror is done with three screws around the mirror, which can be reached through holes in the tube. They are located on the north, southwest, and southeast side of the mirror. This collimation procedure has not been done for a long time - all we know about it comes from handwritten notes from 1962 kept by Robert Waland, the engineer and mastermind behind the JGT. The adjustments were made in an iterative process in between taking photographic plates.

Soon after the inauguration of the telescope it became clear that the images suffer from spherical aberration, due to an imperfect figuring of the corrector plate. The issue seems to be mostly confined to the outer regions of the plate. In the late 1960s, after considerable deliberations, the telescope was adjusted to mitigate the effects. This included moving the primary mirror slightly backwards by 1.4 inch, with the result that the focal plane is now inside the hole of the primary mirror, contrary to what is shown in the sketch above. This limits the field of view and the room for instruments. In the 1960s and 70s the telescope was operated with about 5 square degree sized photographic plates, mounted on a plate holder, that goes into a tube that sits in the hole of the primary mirror. That tube is movable and can be adjusted to that the plate sits precisely in the focal plane.

According to recent calculations of van Breda, the corrector plate is inaccurate by fractions of a millimetre. The following figure shows the profile of the Schmidt plate as made (red) compared to as designed (blue). At a radius of 40cm, the depth of the trough is 19 micrometers too deep. This radius corresponds to about an aperture of 32”. Replacing the Schmidt plate would be the most rigorous way to solve this issue.



The point spread function broadens away from the optical axis, due to some coma or astigmatism, probably only leaving 15’x15’ or so with good seeing. The spatial dependence of the PSF also changes as a function of aperture. At the largest apertures, the PSF develops an asymmetric halo across the chip, even close to the optical axis. Reducing the aperture to 32-33 gives a slightly more circular PSF in the center without halo, but does not get rid of the spatial inhomgenity. For applications with small field of view that do not require maximum aperture, it is recommended to observe with small aperture.

Until 2018, CCD cameras were operated behind the primary mirror and the focal plane. This setup used two rather mundane lenses, one in the focal plane, one in the filter wheel, to relay the focus to a plane behind the mirror, where the CCD is mounted. These relay lenses introduced significant vignetting and new distortions of the off-axis stars. More on this in the chapter about the backend.

The maintenance of the optics has recently been limited to cleaning of the upper surface of the corrector plate every few years. This is now carried out with a product called First Contact, a polymer solution that is sprayed on the surface and hardens to a film, which can then easily be peeled off with all the dirt, without having to touch the surface. For this procedure, we move the telescope to hour angle of 12h westwards and a declination of 42 deg or so, and the platform by a meter to the east. In this position the corrector plate can be completely accessed from the elevated platform. The cleaning should only be done with the dome open to allow for proper ventilation. The picture shows the corrector plate before and after the routine in July 2013.

July 2013: Cleaning the corrector plate of the JGT

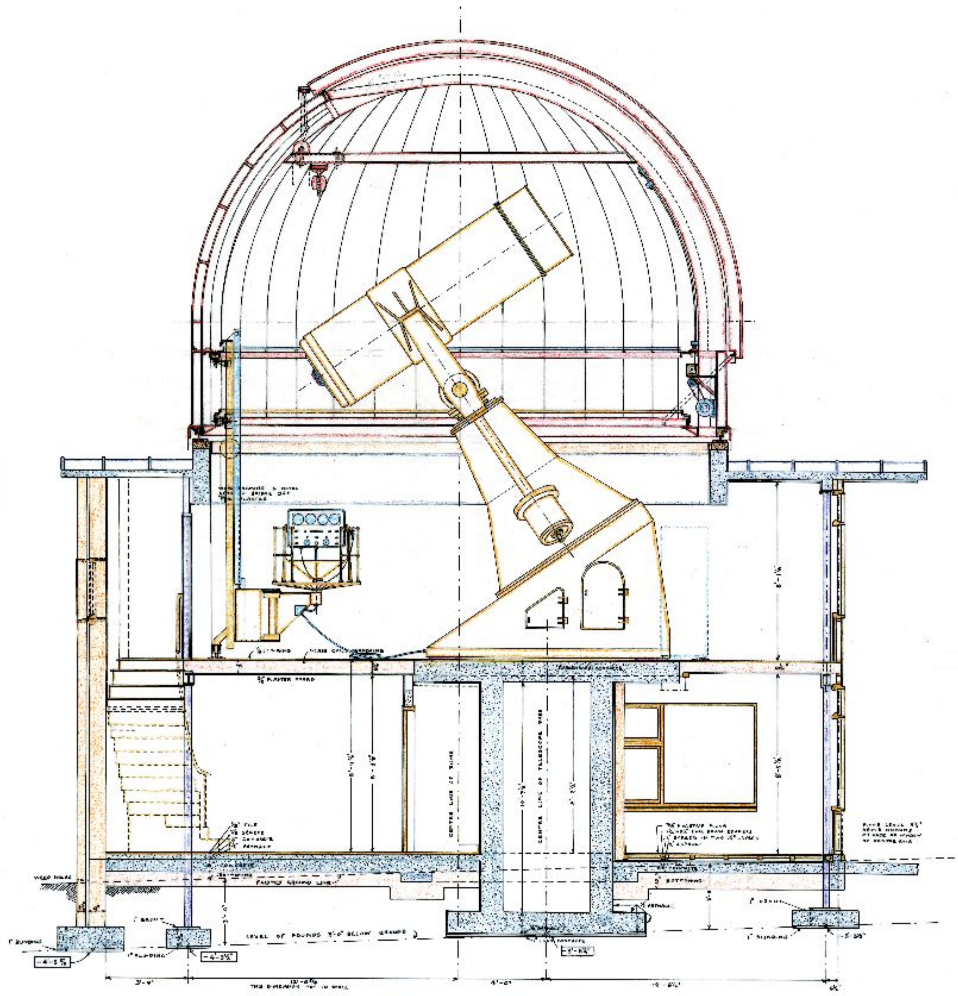
before cleaning after cleaning

The re-coating of the primary mirror has only been done once in the history of the telescope, and that was in the early 1980s. We do not know a lot about this procedure, apart from a set of handwritten notes, which are now available in digital form. We also have a relatively recent quote for the recoating over 6000 pounds, from Thin Metal Films Ltd, contacted by ATC in Edinburgh. This would not include the shipping. So far, we have successfully managed to postpone this major operation, under the argument that the mirror looks okay and it does not seem urgent. But some day someone will have to be brave and try it out again.

The Gregory building

The Gregory building is fittingly the home of the James Gregory Telescope. It is the largest dome at the observatory in St Andrews, located just off the parking lot, very hard to miss. The building has a ground floor with three rooms and an upper floor which is the dome. In the southwest corner of the dome is the machine room, filled with computers and gear. At the southside, towards the parking lot, is a small balcony, helpful to check the weather. There are various little closets, a toilet on the ground floor, and two entry doors. The main entry is on the west side towards the trees.

The building was conceived and planned by the first director of the observatory, Erwin Finlay-Freundlich. Only at first glance it is a bland building. If you look close, there are many interesting design details. The building has a trapezium shape, with the larger baseline towards the south. The south front, the face of the building, is cladded with wood (which was entirely replaced and refurbished in 2014). For more evidence of purposeful design, look at the windows, the staircase railings, and the brass furnishings at the doors.



To do a quick tour: After entering the building on the west side, we are in the hallway which currently houses the oldest telescope at the observatory, a Dallmeyer scope from 1870 or so. The first door to the right is the control room, named after Elizabeth Lumsden who sponsored the refurbishment of the building in 2013-15. This room is spacious and used to be a mapping room. Now we use it to remotely control the telescope. It is the space where observers spend the night. The telescope control machine is installed on a bench at the far side of the room. The second room accessible from the hallway used to be a darkroom, and is now mostly a JGT archive, with two cupboards filled with drawings and documents about the telescope. The third room on the ground floor is in the southeast corner and has its own door to the outside. Currently it is used by the millimeter wave group in physics. The astronomers do not have access. Quite obviously, the staircase leads upstairs to the dome.

The building's only purpose is to house the big telescope. The weight of the telescope is resting on a concrete fundament in the center of the building. The rest of the building is not deeply anchored into the ground. There is a hatch in the dome floor that has the right size to lower the primary mirror into the hallway. The main entrance is sufficiently big to move the primary mirror out of the building, in case someone wants to recoat the mirror.

Some essential information: The wastewater from the building flows into a septic tank located towards the north, between Gregory and Napier building. The mains fuse boxes are in the cupboard on the right side of the hall way, which also holds cleaning utensils. The network cable comes in through a duct from the CREEM building that ends at the southeast corner of the Gregory building.

The autoguider

Introduction

Although astronomical telescopes are usually designed to be able to follow the motions of the stars, this tracking procedure is never fully accurate, due to various reasons. A common way to overcome the tracking inaccuracies is to add a guiding system. In the case of the JGT, guiding is historically done with an extra telescope mounted on the main tube. The guider telescope is a refractor, with an 8” lens and a focal length of perhaps 2.5 meters. The lens itself consist of two components, with a narrow air cavity in between. The telescope is permanently mounted and its position cannot easily be adjusted.

The traditional way of guiding is to have your eye pressed against the eyepiece of the guider telescope, a handset in the hand with buttons that allow you to adjust the position of the telescope, and to keep a bright star on the same spot in the field of view, usually aided by an illuminated crosshair built into the eyepiece. But luckily we are not doing that anymore. Instead, an off-the-shelf autoguiding system is mounted at the backend of the guider telescope. This system from SBIG, literally a blackbox, is compact in size and does most of the work automatically. It contains a digital camera and a procedure that finds a bright star, and if successful, keeps the bright star at the same spot of the chip, by sending small adjustments to the telescope control system. To use the autoguider, the observer needs to a) switch the power on at the telescope tube, b) switch the autoguider black box on with a tiny switch at its back, and c) open the lid of the telescope by pulling on a string labeled “open”. These three steps are part of the startup procedure for advanced observers.

The telescope is unfortunately a rather slow optics in terms of focal ratio. The field of view of the autoguider is small, about a quarter of the field of view of the current CCD at the main telescope, maybe 5’x5’. The field of the autoguider is covering the lower left corner of the CCD field, to the southeast of the centre, but this depends slightly on the orientation of the telescope. It is also not a square, but weirdly shaped. As a result, the observer needs to place a promising guide star in that part of the CCD and then experiment a little if the guider does not find it right away. A good guide star has at least magnitude 10, brighter is better.

Computer control software

The autoguider camera is set up from a little piece of software, provided by the manufacturer, which is installed in a windows machine that is placed in the machine room. The name of the machine is obs-greg-1 and it is located opposite the control panel, the second machine from the end of the room. The user simply starts the computer (if it is not already on), logs in as “observer”, starts the software with the icon that looks like a crosshair, clicks a button, and from that point onwards everything should happen automatically. The camera software will try short exposure times first, then increase the exposure time up to 10 seconds, and tries to find a suitable guide star. If it finds one, it will start guiding. This results in a table that is continuously displayed and updated. If it doesn’t find a suitable guide star, it will just stop. It is really rather self-explanatory. The communication between the autoguider box at the telescope and the computer is via a serial connection and could in principle be run from any machine.

The software allows a few more settings that normally should not be touched by the observer. For example, it regularly needs to be focused. The autoguider is mounted on a motorised focuser with about 15 mm travel distance, which takes about 25 seconds to drive end-to-end. If there is a really bright star at the right spot, but the guider can’t find it, the camera might be defocused. To refocus, there is a tiny black box near the autoguider computer with a switch on top that can be used for adjustments. The focuser moves fast, so, nudging is better than holding the switch for longer. The camera also has a calibration routine that was only used once in its existence, as far as we know. It is also possible to show the autoguider images on the screen, if absolutely needed (and sometimes this is a nice crosscheck if the search for the guidestar gets too confusing), but downloading an image takes a long time.

Telescope control

The autoguider needs to talk with the telescope to be useful, and it does that in a rather ingenious way, in line with our general philosophy to make use of the old telescope technology. The autoguider operates a box with relays that sits on the same side of the telescope - it’s a roughly hand sized metal box. That box in turn is connected to the control system of the telescope. This connection is in parallel to the connection from the remote handset at the platform and finecontrols the telescope at GUIDE speed. That way, the autoguider in essence mimicks the function of the remote handset - the handset that used to be in the hand of the observer at night.

The autoguider is part of the intricate system that regulates who has control over the telescope. In its current setup, it can take over IF the switch at the top of the control panel is set to AUTO/PC and IF the radio button in the telescope control software is set to ‘Autoguider’. Only then are the signals from the autoguider correctly send to the motors in the telescope, via a series of relays in various places. Apart from controlling one of these relays, the telescope control computer has nothing to do with the autoguider operation. This is the most surprising aspect of the autoguider - it is practically independent of computers.

Calibration

The autoguider needs to be properly calibrated to send just the right signals to the telescopes to move the guide star back into the original position. In essence, it measures a displacement of the center of a star in pixels, then converts this to an electrical signal that operates one of the motors for a certain amount of time. This conversion can only work after calibration. The autoguider software has a routine for that. At the JGT the calibration is non-trivial, because operating the motors for a specific time does not always move the telescope by the exact same amount. In RA this is made more complicated by the worm error of the sidereal tracking. According to Roger Stapleton's statement, the calibration was tried several times until it worked, and then it was vowed to not touch it again.

The dome

Introduction

The JGT is permanently installed inside a spherical dome. The JGT dome was actually built after the bulky parts of the telescope mount were put inside the building, as the following snapshots illustrate. The dome is not particularly big for the size of the telescope, just big enough to not hit anything when moving the telescope around.

Basic instructions on how to open the dome and how to use it for observations can be found in the startup manual.

The shutter

The dome opens on one side, sensibly. To be able to operate that motor, a cable from the power cabinet needs to be connected to a specific outlet on the dome, shown in the picture - the one on the right with the yellow marker. This cable provides three-phase power and some additional cables. As long as a cable is plugged in, the dome cannot be moved. In standard configuration, the loose end of the cable is placed on the south side of the telescope. Since the dome outlet is more than 2 meters up, a ladder is needed to access it. The dome always needs to be parked in the same spot to put its outlet near the ladder on the south side. The parking position of the dome is reached when a black tape marker on the dome is aligned with a black tape marker on the north-west side of the building.

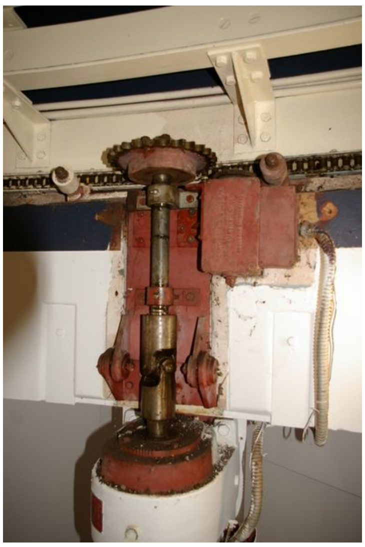
Most of the regular dome shutter mechanism is hidden behind the dome cladding and we don't have pictures. A motor drives a chain that pulls on wires running from one side of the shutter to the other side, and also to the top of the shutter and again to the other side. The wires from left to right are the only part that is visible to the observer. Once the shutter has reached its desired position, a limit switch stops the motion. Another limit switch does the same once the dome is closed again. Those two switches amount to three additional pins in the plug. Two more inform the system whether or not the cord is plugged in. With three phase power, that makes 8 total connections.

In its current setup, it seems as if the shutter is not connected to the telescope at all, but that is not the case. In principle, once the cable is connected, the shutter could be opened from the control panel, and there are even two (disabled) switches for that. Historically, the shutter was powered from the platform, which is connected to the dome. This probably also explains why the JGT was not built with a dome that is permanently powered - it was simply not necessary because the observer was always on the platform. The current awkward ladder climbing excercise is not trivial to overcome - we would need a system that can align the dome with an outlet at the building and then attach one to the other automatically. This might be one of the most difficult challenges on the path to a fully remotely operated telescope.

The same job, opening the dome, can also be achieved with the emergency dome motor shown in the picture. This looks weird because it is at an angle to the dome wall. It has to be, to be at a right angle to the shutter, which is to the left in that picture. This unit might have been a generator of some sort in its previous life. The surrounding electrics is quite complex and unfortunately exposed to the elements. It is powered by an emergency DC battery connected to the right of the pair of outlets on the dome.

Dome rotation

The dome rotation is driven by the strongest and loudest motor in the Gregory building. It is operated from push buttons in the control panel and handset, which switch connectors in the cabinet. The actual unit is located in the obvoius white tube on the south side of the dome. The pictures shows the dome rotation apparatus with the white cover off. There is not a lot under the cover. The motor at the bottom includes a gearbox. The universal joint above the motor connects to a sprocket that is pressed against the dome by two springs, one on either side.



This is the view of the sprocket and the springs, which hold it against the chain that is running all the way around the dome.	
On the right hand side in both pictures aboe is a red box which seems to contain some sort of limit switch. This box is redundant and is not doing anything useful right now. The gear wheel on top is not connected to anything. The shaft is threaded and is probably supposed to move up and down, maybe to detach contacts and to stop the dome from moving. We can only speculate what this was supposed to be, perhaps a dome parking mechanism?	

The auto dome

Since 2013 the dome has an automatic tracking capability that allows us to follow the telescope as it is moving with the stars. This was an important step that made it possible to move the control room downstairs. The auto dome was conceived and implemented by Roger Stapleton, following a similar implementation found at the University of Louisville. The solution consists in RFID tags fastened to the inside of the bottom of the dome, and RFID readers to tell where the tags are. For the JGT implementation, Roger used 144 RFID tags glued to the dome. Three readers are stuck to the building and linked to the telescope computer. The telescope control software reads the position of the RFID tags as they pass the reader and calculates the position of the dome within a few centimeters. In addition, the software has a model to calculate which way the dome should be pointing for a given telescope position. This model is based on empirical measurements, done simply by moving the telescope to a number of positions, adjusting the dome position so that the telescope can look outside, and then reading off the dome azimuth. The model is then an exercise in spherical trigonometry.

In addition to knowing the position of the dome, the software also needs to be able to move the dome. This is achieved through two relays, replacing the dome movement buttons on the handset. The only issue is that the dome is not stopping immediately when the button is released. It keeps moving for about half a second, because it's heavy and has a lot of inertia. Therefore, the control software has to wait until it has really stopped. The software also has to account for electrical noise and spikes from the control system which affect some of the USB interfaces to the readers. This makes the software side of the auto-dome surprisingly complicated - but fortunately invisible to the observer.

Dome maintenance

The dome needs a little bit of regular maintenance, but not much. There are greasing pins around the base of the dome, which can be used to re-lubricate the rail on which the dome is moving. The chain could be cleaned and re-greased as well. The chains and wires that operate the shutter can be tightened and lubricated as well. All these jobs are fairly straightforward and can be done from a ladder or the platform.

The platform: an illustrated guide

The platform in the dome used to be the place for the observer. Now it is exclusively used for maintenance purposes. It is meant to provide people a way to access to the focal plane of the telescope, no matter where it is pointing. Today we abuse the platform to get to the main mirror, the DEC axis, or the fork, whatever needs repairing.

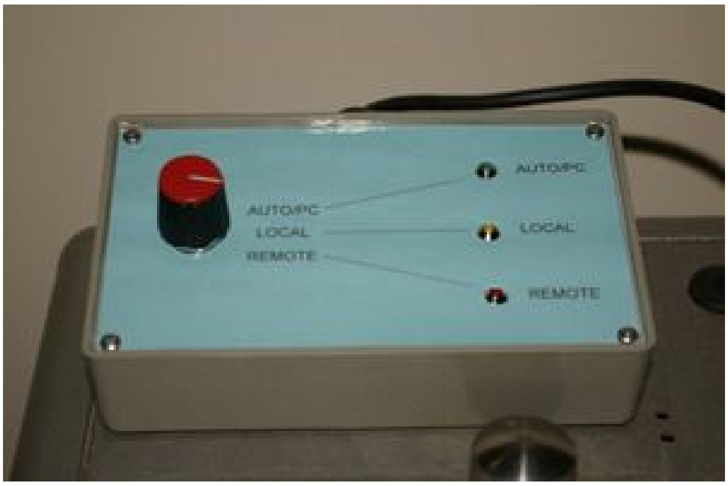
These two pictures show the platform in the normal parking position. This is how observers expect it to be. The ladder is down, the gate is open, the red rail is down, and all cables should be stowed. There shouldn't be any cables on the floor (although there is one in the image, apologies).

The following is a sequence of steps for using the platform for maintenance or repair jobs:

1. **Connect power and control cable.** Those cable are normally stowed on the lower rungs of the ladder behind the platform. They are looped, not coiled, to prevent them from getting into an ugly tangle. Take the cables off the ladder and connect the power and control to the bottom of the telescope, as shown in the images below. Now switch the power on the control cabinet in the machine room, see startup instructions.

2. **Connect handset cable.** The cable should be on the platform, laid out in a way to prevent tangling. Lay out the full length on the floor. Connect the plug to the outlet on the telescope, located near the mirror cover handle at the bottom of the tube The black markers should be aligned. Really make sure that the cable is properly connected.


3. The platform can now be operated with **the handset** shown in the picture. To use the handset, switch the selector shown in the right image to REMOTE. This selector is in the machine room on the control panel. With the handset, the dome can be rotated, the telescope can be moved in RA and DEC, and the platform can be operated. For the latter, the hydraulic pump has to be on - this is done with the red switch at the top and causes a loud noise. Pressing the button again switches the pump off. It’s a good idea to try this out before standing on the platform.



4. **Move the platform to the desired position.** This might not be necessary, but if it is, two metal plates at the back of the platform need to be removed to allow the platform to move - see image. Normally these plates stop the platform from moving when the dome is rotated. There are two of these plates, one on the east, and one of the west, but if the platform is only moved one way, only one of the plates need to be removed. Once the plates are removed, push the platform very hard in the desired direction.


4. **Prepare the platform.** Climb onto the platform. Make sure you have everything you need for the task you are trying to accomplish. Raise the red rails by pulling and fix them at full height with a locking pin. Close the gate and fix it with a locking pin. Raise the ladder with the chain and the dog leash, and fix it upright with the pin. Fixing the ladder is slightly complicated - there are multiple ways to do this, one of them is shown in the picture on the right.


5. The platform can not only go up and down, it can also pivot. To enable this, **a pivot pin** needs to be removed. The pin is on the back side of the platform, accessible if you are standing on it.

Now the platform can be used. The picture shows Stephen King on the platform high up in the dome and pivoted outwards.

When finished, reverse everything we just did. Here is a quick rundown of the parking procedure for the platform.

- Lower the platform to the bottom of its travel.
- If the pivot motion has been used, pivot fully towards the ladder.
- Insert pivot locking pin.
- Lower ladder.
- Open gate and fix with hook in half-open position
- If the platform has been moved sideways, lift steps off the floor and push it back to its parking location and lower the steps to the floor.
- Replace the plate(s) that stop the platform travelling.
- Lower red railings
- Switch off 24V and 3-phase supplies and set handset to 'local' in control room.
- Disconnect and stow handset.
- Disconnect and stow power/control cable.

Using the platform is usually a two-person job, one on the platform and one on the floor of the dome, ready to jump into action if something goes wrong. A second pair of eyes is also good to spot any issues and mistakes while using the platform. The hydraulic motor is really strong and can absolutely destroy things in its way, if not operated properly. It is a good idea to wear a hardhat and to doublecheck everything before operating the platform.

More (but perhaps outdated) advice is found on [Roger Stapleton's help page] for the platform - from which I have taken all images.

Mechanics

The section on the JGT mechanics is going to be relatively short.

Three sets of documents are available that give insights into the mechanical system of the JGT: a detailed collections of drawings on paper, stored in the former dark room in the Gregory building; footage of some aspects of the assembly, available in digital form; and a document written in 1980 by Roger Edwyn that outlines the procedure of removing the primary mirror (for the purpose of resurfacing). Changes to the mechanical setup have been very limited. Apart from the mirror resurfacing and the adjustments to the mirror position, outlined in the section on the Optics, no major changes have been made.

The most common adjustment to be made is the addition or subtraction of weight at the backend of the telescope, to rebalance the system after changes to the detectors or computers. The JGT is very finely balanced, and every change that exceeds a few kilograms need to be accounted for. Around the mirror cell are tabs that take on a set of weights, each a few kilograms of metal, stored usually in the cupboard in the north-east corner of the dome. By carefully accounting for all weight that comes off or goes on the telescope and adding or subtracting the corresponding weight the system can stay in balance.

Dataflow

In this section we will look at the computer system associated with the JGT, and how the data is communicated between machines.

We start with a list of the available computers:

- The machine that controls the telescope (or most of it) is called *quadrans*. It is a Linux box physically located in the upstairs machine room, the computer farthest away from the door. This machine has hardware links to the encoders at the base of the telescope and to the RFID readers in the dome, and through these links it knows the position of the telescope and the position of the dome. It runs a control software, and nothing else. An identical copy of *quadrans* is located in the Napier building, and it's called *muralis*. Both machines run Scientific Linux 6, hopefully soon 7.
- At the side of the telescope is *obsccd2*, another Linux box that runs the Andor camera. It has to be on the side of the telescope, because it talks to the camera through a specific interface that cannot easily be put to a long link. The machine runs Scientific Linux 7, and hosts the camera software. It can also run image display software Gaia and ds9. An identical copy of *obsccd2* is in the Napier building.
- The autoguider system is controlled by *obs-greg-1*, the only Windows box at the observatory. It sits next to quadrans in the machine room and is always on. Apart from the software to start the autoguider, it also can be used to run cameras with a USB link, i.e. the SX Trius or the QSI.
- In the groundfloor control room we have *jgt-control*, a iMac whose specific purpose it is to run remote machines and devices. This is the machien the observer controls during the night. Before aquiring this machine, the remote control was handled from a Linux box, but this setup had serious trouble handling a multitude of screens and windows. This Mac has a permanent sftp connection to the data directory on *obsccd2*. It also is configured with two windows running ssh connections to *obsccd2* and *quadrans*.
- Another Linux box located in the machine room is *fornax*. Until a few years back it was used to run a customised pipeline for planet hunting, but this convoluted software is now outdated. For now this machine functions primarily as archive (see below). The data drive of *obsccd2* is mounted at *fornax*, giving it access to all images.
- Roger Stapleton's machine ansa is placed in his office in the Napier building. At this point, this computer is primarily for his personal use and for operating the multi-stage backup (see below).
- Finally, *obspi1* is a Raspberry Pi mounted in a Lego enclosure. This little thing is running the all-sky camera (SX Oculus) on the pole on the south side of the dome. It also has its own little camera on the front side.

All these machines are on the network (with some issues for *obspi1*) and apart from the ones directly linked to the telescope they are visible from the rest of the university (although probably not from the outside world). The IP range at the observatory is 138.251.60, and then numbers ranging from around 50 up to 77 or so, but it's easier to talk to machines by name.

If the Andor camera is used, the pictures will be stored on *obsccd2* while observing. In the morning a multi-backup routine is ran. At 8am, a cronjob on *fornax* runs an rsync command to mirror the data directory on *obsccd2* (mounted on *fornax*) to the /backup directory on *fornax* itself. At 9am, another cronjob on *ansa* runs rsync to mirror the data directory on *obsccd2* to four other machines on the network: /obsdata/jgtdata on *ansa*, /polaris/jrs/obsdata/jgtdata, /polaris/obsdata/jgtdata, /obsdata_2/jgtdata on *ansa*. Polaris is a server in the School of Physics & Astronomy maintained by Ian Taylor. For completeness, the complete *polaris* disk should also have a backup. After that, there should really be a sufficient number of copies. By using rsync, the backup only happens when there is new data.

For USB controlled cameras, the pictures are taken with the software Nebulosity and stored directly on jgt-control. This machine has a backup disk in the same run operated by TimeMachine. So far, the data from USB cameras is occasionally copied to *polaris* by hand. /polaris/obsdata should contain the entirety of the observatory images. In the future, the data directory on *jgt-control* should be automatically archived on *polaris*.

All data in the archive is unreduced and without coordinate system. One future job is to implement an automated and streamlined reduction scheme for all JGT images and publish the results. This would facilitate a more systematic exploitation of the archive. First steps in this direction have been taken, but completion requires significant work. The full JGT archive currently contains nearly 400 Gigabytes of data (in 2018). Its value is the high-cadence time series imaging over durations of several hours that was obtained over many years. So far, only a fraction of the data has been properly analysed.

So far, the images can only be accessed locally or by being connected to one of the Linux boxes that is part of the astronomy cluster. There is no external access to the archive. A possible future idea is to maintain our own public image server at the observatory (presumably placed in the Napier building). How exactly to do that remains unknown.

Staff and responsibilities

The JGT is part of the University Observatory in St Andrews, which in turn is part of the School of Physics & Astronomy. Currently four people are directly involved in the maintenance and operations of the JGT:

- **Aleks Scholz** is an astronomer employed as Observatory Director, on an open-ended permanent contract. The current post was created in 2013. The Observatory Director is a regular member of the teaching staff and therefore participates in undergraduate and postgraduate teaching. He also runs his own research program. However, a generous part of his teaching workload is reserved for work at the observatory, including the JGT. The Observatory Director is primarily responsible for the administration of the telescope, the supervision of the observing program, the funding, and the promotion.
- **Roger Stapleton** has a honorary position at the university. Since his retirement in 2004 he volunteers parts of his time primarily for the technical development of the JGT. With his expertise on all aspects of the JGT - including mechanics, electrics, IT - and his background in physics and astronomy, his contributions are incredibly valuable. His main project is the conversion of the JGT into a remotely operable digital telescope. In addition, his work includes the administration of the JGT computers as well as the diagnostics of failures and planning of repairs or developments.
- **Stephen King** is a member of the School workshop whose job includes technical duties at the observatory. He carries out regular maintenance at the JGT, takes over mechanical jobs, manages the buildings, and coordinates with the workshop. This position was created in 2017.
- **Mark Ross** is one of two members of the electronics workshop in the School and has continuously been involved in maintaining and upgrading electrical components of the JGT for a number of years. Among many other jobs, he is primarily responsible for developing the sidereal tracking system.

In addition, various members of the workshops in the School contribute to the work at the JGT, depending on current requirements. Well-constrained small-scaled tasks are often carried out by students in summer projects or as final year projects. PhD students in the astronomy group usually contribute to the organisation of observations and to the outreach program.

Altogether the work currently done around the JGT might amount to a full-time position. This level of staffing is sufficient to maintain the status quo and do some useful teaching and research, but it is not sufficient to carry out any large developments and significant research projects.

Funding

It is fair so say that the JGT is operated on a shoestring budget, and has been for quite some time. The following is a hopefully complete account of funding sources that is available for equipment, repairs, and renovations. In addition to what is listed below, the university supports the staff members who are in charge of the JGT, which amounts to about one full-time position (but for the entire observatory).

The primary source of funding for the JGT is an annual budget for astronomy labs that is paid from the operations budget of the School of Physics & Astronomy. This pot amounts to 10K to 15K GBP for each financial year, but it has to cover all astronomy lab equipment, including lab computers in the School, small telescopes, radio telescopes. It is also used to support the annual postgraduate observing trip and various other teaching-related expenses. Sometimes summer projects are funded from this pot as well. On average we are probably spending a few thousand pounds per year from this budget on the JGT. This covers routine repairs and maintenance, but does not allow us to acquire expensive equipment, like new cameras or optics.

For comparison, to buy a full night of observing on a non-profit 1-m class telescope costs from 1000 GBP upwards (see for example the pricing of the SMARTS collaboration or the LCO network). For a typical year with 50 observing nights, each several hours, we would therefore expect an operations budget of perhaps 20-30K GBP per year, excluding staffing. That level of funding would allow us to acquire up-to-date instruments, offer compensation for student observers, and support outreach activities, which in turn would again lead to more productivity and possibly income.

Over the past decade, external funding has been acquired for the JGT on multiple occasions and for specific purposes. A private donation was made by Elizabeth Lumsden to establish an accessible ground-floor control room. This grant covered the parts for the auto dome, a few other technical upgrades at the telescope, the renovation of the ground floor, and the equipment for the control room (all from about 2010 to 2015). The same range of activities was supported by a private donation from SpanOptics in Glenrothes. Both grants were negotiated by former Observatory Director Andrew Collier Cameron. Another external grant was a Small Award for Public Engagement from STFC, a total of about 6K acquired by Aleks Scholz and used mostly for outreach activities around the JGT in 2014 and 2015. In 2017, Space Insight Ltd, a company leading the UK Space Agency's space debris survey efforts, headed by St Andrews graduate James Dick, awarded us funding of abou 7K to acquire a new CCD camera, the Starlight Xpress Trius 36, plus a set of filters, for the purpose of monitoring space debris.

Ideally, the meagre funding for the JGT would be more regularly complemented by external sources. This has turned out to be challenging, for the simple reason that the JGT is mostly useful for the University of St Andrews, and not particularly useful for anybody else. Attempts have been made to include the JGT in applications for research funding, but so far unsuccessful. Alternative funding sources for the heritage aspect of the telescope have been explored, but so far not pursued to not endanger the research environment. The outreach program might at some point put ourselves in the position to work towards crowdfunded projects.

Outlook

One principle that has been followed throughout the project is to make this an add-on to the existing control system. Nobody understands the whole system in detail, it works, so let's not break it!

The above quote by Roger Stapleton describes perfectly our current approach to the development of the JGT. While the telescope is always changing and hopefully improving, we aim to maintain its core functionality. Partly because it works, but also because this leaves us more options for the future.

The JGT is now more than fifty years old and in an interesting phase of its existence. Over the past decade it has been used more regularly than over most of its lifetime. It runs without major problems and is now well promoted within the University and in the St Andrews community. On the other hand, large research telescopes do not typically live for significantly longer than 50 years (with a few notable exceptions that benefit from good sites and exceptional circumstances, like the big telescopes on Mt Palomar). At the JGT, the lack of funding and staffing as well as the location at sea level and the corresponding 'interesting' atmospheric conditions place severe constraints on the research programs. Therefore we need to keep thinking about the purpose and possible applications for this unique telescope. We are absolutely determined to prevent the JGT from becoming scrap metal and glass, like so many old telescopes in St Andrews and elsewhere.

There will always be worthwhile research avenues for a telescope of that size, if it is keeping up with the technical advances and is kept in good condition. A good example is the search for exoplanets using the transit method. For almost a decade the JGT was part of the Super-WASP project, the most successful ground-based search for transiting exoplanets, and has made important contributions. This was only possible because the JGT has a CCD camera and a computer system that allows real-time image processing. In recent years, work on variable young stars, asteroids, and active stars has also produced publications. We are dedicated to finding attractive research programs for the JGT, to keep it up to date, and to use it for research for as long as possible.

Research at the JGT is not necessarily done only for the sake of producing papers, although this is a good by-product. By and large, we do not need the JGT for the research that is currently conducted in St Andrews. But compared to all other telescopes the JGT has a specific advantage for us - we are one of very few universities with a professional telescope of decent size right on our campus, easily accessible, within walking distance of the School and the town. It is a hands-on telescope which perfectly demonstrates many of the technical challenges of observational astronomy. Therefore, we should use it to show our students how to conduct research with big telescopes, how to operate a complex machinery under complicated skies, how to use a telescope with a digital camera to gain information about stars and galaxies. This is the real value of the JGT - *it is a teaching telescope that does research.*

We should also use it to explain observational astronomy and the way it is done today (and in the past) to the general public. There is a widespread fascination with the big telescope in St Andrews and surroundings, and every year hundreds of people visit the dome to see the machine in action. As a local telescope, the JGT can be used to stimulate enthusiasm about astronomy (and other STEM subjects), to showcase research programs, and to enter into a conversation with interested members of the public. The JGT dome can be the place where school children experience astronomical research for the first time. In light of these opportunities, we should strive to keep it open, well-documented and accessible for as long as possible.

The overall plan currently followed at the JGT can be summarised in three points:

1. **Turn the JGT into a remotely operated telescope with digital user interface and flexible configuration, to keep it interesting for future research applications.** Important parts of this plan have already been achieved in recent years, but a number of technical upgrades are still missing. We aim to achieve a larger field of view, better image quality, more control over the sidereal tracking, more guiding options, and a more streamlined user experience from the downstairs controlroom.
2. **Integrate the JGT into the curriculum and the student experience at the university, as our local big telescope.** All astronomy students in St Andrews should have a chance to work with the telescope. All students with interest in astronomy should have a chance to visit it and see it in action. Important steps towards these goals are to maintain an accessible documentation of the JGT and its products, to maintain teaching facilities at the observatory, and to promote the telescope within the School and the University.
3. **Make the JGT accessible to the outside world - turn it into a 'transparent telescope'.** We aim to find ways to make the operations of the telescope and the obtained results accessible, to visitors in St Andrews and online. In the future we want to achieve a state where visitors can watch the JGT in action, take their own pictures, and remain in touch via the online community.

These three goals address three applications for the JGT - for research, teaching, and outreach. All three aspects are interlinked. We hope that the JGT can be a place where research, teaching and outreach happens at the same time. Where astronomers can instruct students to carry out their research programs, while visitors spend time under the stars and watch the big telescope in action.

Imagine a clear winter night in St Andrews. A trained postgraduate student moves the telescope to our target, a cluster of young stars embedded into a nebula. A group of visitors hears the story of the JGT from member of staff. Outside, an undergraduate class is instructed in using smaller telescopes. Before we start observing, we put an eyepiece into the JGT and look at the reflection nebula with our own eyes. Some people might prefer to take pictures through Scotland's largest telescope with their phones and post them on social media. Then we move the camera in place, and the observer starts taking scientific data. Some visitors and students are keen to see the digital images from the JGT in the control room. Others remain in the darkened and open dome, and peer with the telescope into the stars.