JODRELL BANK OBSERVATORY 7-M RADIO TELESCOPE: OBSERVING MANUAL

The Jodrell Bank internet Observatory (JBiO) is a web interface to Jodrell Bank's 7-m radio telescope. The telescope itself is actually controlled by a VAX computer running a VMS operating system. The software which handles communications between the telescope and the web server will only be running at the times designated for internet observing. Access to the telescope is obtained from the web page http://www.jb.man.ac.uk/distance/observatory.

1. The Telescope Monitor

When the internet observing software is running, the telescope sends information about its current status to the web server and this can be displayed using the **Monitor** link at left. If you click on this link the monitor information will be displayed in this page. If you like, you can open it in a new window by right-clicking the link on the menu bat at left, and selecting 'Open in New Window'. This page will refresh automatically every 10 seconds with the latest data from the telescope. You can see the time at which the information refers to at the top of the screen. If it looks like this is not updating you can try manually 'refreshing' (or 'reloading' if using a Netscape browser). If this does not give recent (i.e. within last 10-20 seconds or so) information then check whether the telescope is supposed to be performing internet observations at the moment. The current schedule is summarised on the 'Home' page of this website - click on the **Home** link on the menu bar. The only other thing that might stop observing is mechanical failure of the telescope (thankfully rare) or weather (high wind or heavy snow) - you can check on the local weather conditions by going to the Jodrell Bank Live page at www.jb.man.ac.uk/vlbi/inter/jblive.html and looking at the details of one of the local telescopes (Lovell, Mark II or 42ft).

An annotated example of the **Monitor** screen is shown below:

Control:	Local		What is controlling the telescope - when using the web interface this should read 'Local'
Time (UT):	12:32:27 13/12/2004		This is the time (according to the Telescope Control Computer) at which the information was sent to the web server - hh:mm:ss dd/mm/yy - this is Universal Time, remember your time zone may be different from this; all observations must be set up in UT
MJD:	53352		Modified Julian Date. The number of days since midnight on 17 November 1858
Observer:			Name of current observer plus a 10 digit number uniquely identifying this observation made up from time at which the observation was made in yymmddhhmm format
Coord system:	GALACTIC		Either galactic, equatorial or Alt-Az
Coordinates:	120.00	0.00	(Long, Lat) if galactic; (RA, Dec) if equatorial; (Alt, Az) if Alt-Az.
Motors:	ON		If the telescope is working these should be ON!
Observation:	NOT OBSERVING		Either Not observing, Waiting, On Source, On reference, Scanning etc.
Telescope:	TRACKING		Either Tracking, Off Source, Calibrating, etc.
Received power:	0.21		Total power currently being received in dB (i.e. a change of 3 in this number is a factor 2 in received power)
Observing Freq: (inc. LSR & vel)	1419.958		In MHz - should be around 1420.406 but usually has an offset due to the motion of the telescope with respect to the Local Standard of Rest (LSR), or because of observing a source with a given Doppler shift (from its velocity) or if a frequency offset has been explicitly requested for calibration (as in this case)
Secs. Remaining:	0		Time left on an observation
	Azimuth	Elevation	Azimuth is degrees east of North, Elevation is degrees above the horizon
Actual:	269.97	57.90	Where telescope is pointing now
Demanded:	269.81	57.90	Where telescope wants to be pointing
Errors:	0.024	-0.002	Difference between actual and demanded positions - significantly different from zero only when telescope is driving towards a new position
Offsets:	0.000	0.000	Only non-zero if the telescope has offsets set away from its nominal pointing position (e.g. while scanning)
Right click to manually refresh Last updated: Mon Dec 13 12:32:32 2004			This is the time according to the communications software at which the monitor information was recorded

2. Webcam

Clicking on the **Webcam** link in the menu bar will launch a separate window in which you will get an image of the 7-m telescope which updates every 30 seconds. The view is towards the east (Figure 1). The date/time at which the image was taken is shown at the top of the image - if it does not appear to be updating then right click just below the image and select 'Refresh' (in Internet Explorer, or in Netscape select 'Reload Frame'). It isn't essential to look at the **Webcam** image but it is sometimes nice to convince yourself that when the **Monitor** tells you the telescope is slewing to a new set of coordinates it really is moving!

Figure 1: Live webcam image of the JBO 7-m

3. Skymap

Clicking on the **Skymap** link gives a live map of the sky above Jodrell Bank Observatory, as shown in Figure 2. This is looking up at the sky so North is at the top, South at the bottom, East at the left and West at the right. The concentric circles are of elevation above the horizon labelled every 15 degrees. The plane of the Milky Way (galactic latitude zero degrees) is shown as a curved line running across the sky. It is labelled with galactic longitude in degrees. Various radio sources (and some visible constellations) are also indicated. The sign of galactic latitude can be determined by noting that Cas A and Tau A are both at negative galactic latitudes (i.e. towards the Galactic South Pole). Hence positive galactic latitudes will be on the other side of the galactic plane from these two sources. The position of the 7-m telescope is shown as a target-like crosshairs symbol. When the telescope is asked to move to a different position another set of crosshairs appears which shows the demanded position. The image updates automatically every 10 seconds. If the image fails to appear you can just wait 10 seconds until the next automatic refresh.
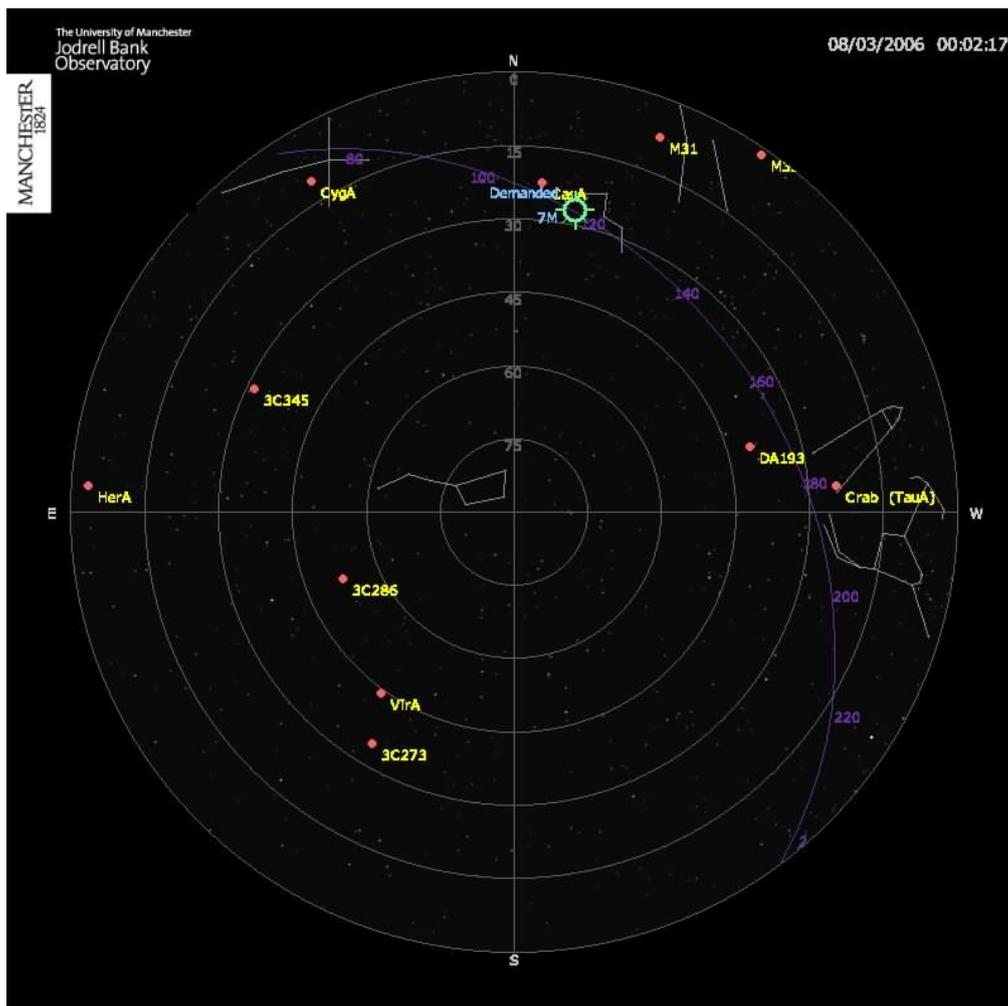
Figure 2: The Skymap image shows a representation of the sky above Jodrell Bank Observatory, and the current pointing position of the 7–m radio telescope.

4. Setting up an Observation

The process of setting up an observation will seem complicated and lengthy at first, but once you have tried it a few times it is actually quite straightforward and only takes a few minutes. Clicking on the **Setup Obs** link will access a page which allows three types of observations to be set up. You will be asked for your **username** and **password** when you first click on **Setup Obs**. There are a number of stages which are dealt with in detail below:

1. Decide on your target i.e. its coordinates
2. Check when your target is available for observation i.e. when it is above the horizon
3. Check the schedule to see which timeslots are available. Remember that these timeslots are in Universal Time (UT)
4. Set up all the details of your observation (e.g. coordinates, reference, integration time, timeslot etc.) and submit to the web schedule
5. When you're happy your observation is correct, flag it for submission to the telescope scheduling computer
6. If all goes OK sit and wait for the observation to occur in the timeslot you requested
7. Once the observation is finished view the data, carry out any analysis required and think about whether another observation is necessary

5. Target Choice

The position of a target will be expressed in either galactic or equatorial coordinates. Galactic coordinates are longitude and latitude with respect to the plane of our own Galaxy, the Milky Way. Basically anything along the plane of the galaxy is at latitude 0 degrees, 90 degrees is perpendicular in a direction 'above' the plane and -90 directly 'below' the galactic plane. Longitude 0 degrees is towards the galactic centre increasing in the direction the Sun is moving, to the 'left' as viewed from the Earth. The position of an object in the equatorial coordinate system is expressed as Right Ascension (RA) and Declination (Dec). These can be understood as a projection of the Earth's longitude and latitude (respectively) projected up onto the sky. Hence objects directly above the North Pole have a declination of +90 degrees, above the South Pole of -90 and above the Equator of 0 degrees. The Right Ascension is measured in units of time with 24 hours marking 360 degrees since the Earth rotates once in 24 hours. Zero hours RA is defined by the position of the Sun at the Vernal (Spring) Equinox as it passes over the equator on its way from the Southern to the Northern sky. This means that objects with 0h RA are overhead at around midday on 21 March. Here, technically we should say 'on the meridian' rather than 'overhead' - the meridian is the line on the sky running from north to south and passing directly overhead the observer. This changes by about 2h every month (making 24h in a year) due to the Earth's motion around the Sun. Hence towards the end of June (3 months after 21 March) objects of 6h RA will be on the meridian around midday and around midnight (12h later) objects of 18h RA will be on the meridian. Once you have the coordinates it is useful to know at what time of day or year the object is visible above the horizon. This is the next step in the procedure.

6. Target Track

By clicking on the **Target Track** link in the menu bar at left you can access a utility which will convert between galactic and equatorial coordinates and also display the elevation above the horizon of a given object during a particular day of the year as viewed from Jodrell Bank Observatory. Check the elevation of a position with galactic coordinates (120, 0) (i.e. longitude 120 degrees, latitude 0 degrees) for 18 December 2001. You should find it is at a reasonable elevation all day. Now try coordinates (120, -40). This will be at too low an elevation during the morning hours. Note times will be expressed in Universal Time (UT) - effectively Greenwich Mean Time (GMT).

It is important that you assess whether the observation you intend to make will be completed in the time slots you allocate to it. Each 10 minute slot must include time for the telescope to slew to its new target. If you submit an observation on the other side of the sky from one done in the previous time slot, it is probable that there will not be enough time to complete both the slew and the observation. Such observations will stay in the queue indefinitely and will never complete. This may be alleviated by allocating more than one time slot to a given observation. In all cases, try to be sensible about what you are asking the telescope to do.

7. Show Queue & Show Archive

We have broken up the periods in which the telescope is available for internet observing into 10 minute slots. These are all expressed in Universal Time. You will normally be allocated 10 slots of observing time. When you submit an observation, the software will detect whether you have exceeded your maximum number of observing slots. Any single observation can be allocated to from 1 to 4 consecutive slots i.e. no single observation can take longer than 40 minutes. Also, even if an observation only takes 5 minutes the next

observation will not begin until the start of the next 10 minute slot. Of course it may be that another observer has already appropriated a slot you were interested in using. Click on **Show Queue** to display a list of all observations which have been queued for the current session. An example is shown below:

Status	User	Submitted	Scheduled	Slots	Type	Source	Details	Submit	Delete
2	TOBR	Dec-14 14:45	2003-12-18 10:20	2	Spec	105, 10	Details	Submit	Delete

We see here that user TOBR has queued one observation. It was submitted at 14:45 on 14 December and is scheduled to take place at 10:20 on 18 December and lasting for two 10 minute slots i.e. you would be able to submit another observation to start at 10:40. You can access more details of each observation by clicking on the **Details** link. The status field can contain one of 7 numbers:

0: Observation just entered, waiting to be submitted to telescope queue
1: Observation submitted for scheduling, waiting for confirmation from telescope scheduling software
2: Observation now queued and waiting to be done
3: Observation in progress
4: Observation completed
8: Observation rejected by telescope scheduling software - already scheduled
9: Observation rejected by telescope scheduling software - invalid format

Please note that it is possible that an observation which is classed as having begun (status 3) may not complete – perhaps due to another observer scheduling an observation before yours has completed or a telescope/software break down. You can always resubmit an observation perhaps allowing an extra slot to ensure your observation completes. We will periodically remove observations at status 3 which have never completed from the queue.

Any observation which has been completed is automatically removed from the queue and then appears at status 4 (completed) at the bottom of the list obtained by clicking on the **Show Archive** link on the menu bar. In this list, data should be available for any observation by clicking on the **Data** link. Try this on the archive list for any observations with a status 4 green code. An example of the result is shown in Figure 3 where plotting of the data is achieved using a java applet. You must have java installed and enabled for this to work. What you see is a plot of brightness temperature in each of 1024 channels in a bandwidth of 5 MHz. Emission from HI should show up at 1420.406 MHz (here labelled in units of 10^3 MHz i.e. GHz). In general the emission can be Doppler shifted to frequencies above and below the rest frequency hence the spread in the peak shown in the example plot. In this case the hydrogen emission is the complex multiply-peaked structure. The curved background is just due to the continuum radio emission from the sky plus receiver noise. If you like, you can zoom in on a region of interest by clicking and dragging out a rectangular box, click on 'Fill' to zoom back out to the whole graph again. You can also view the data by clicking on 'View datafile'. You can also change the horizontal axis to velocity by changing the selection button below the graph. This is calculated using the (non-relativistic) Doppler shift equation with a rest frequency of 1420.406 MHz. Another useful feature is that you can perform a temperature integral under the emission line by clicking on points on the continuum (the sloping background) to left and right of the line.

You may occasionally see narrow spikes of interference or a pattern of spikes near to 1420 MHz as in the example in Figure 3. It is possible to smooth the data by entering a number into the field labelled 'Median Smooth'. If the number 5 is entered (and carriage return hit) then the plotting program replaces every value in the spectrum by the median of 5 numbers centred on that value – this has the effect of removing noise spikes.

Note that when you first submit an observation it is at status 0 with a red exclamation mark i.e. only just entered onto the queue (we shall see how to do this in a moment). If the observation is left at status 0 it will not occur since it has not been passed to the telescope scheduling system. In order to give you time to check your observation or discuss with colleagues the submission to the telescope is a separate process initiated by clicking the **Submit** link at the right of the table. Although you will be able to see details and view data for any observation you will only be able to submit your own observation by entering a password which you set when the observation was initially placed on the queue. Submission changes the Status to 1 and then the
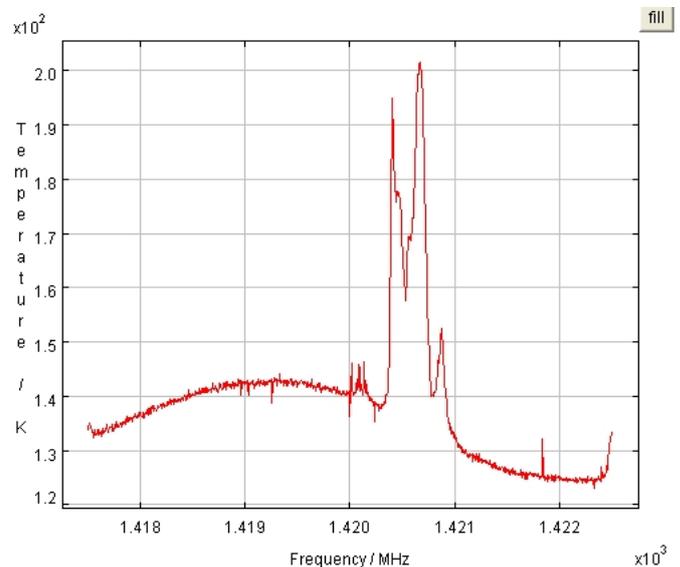

Figure 3: Example of a spectrum taken with the 7-m

web software should pass it onto the telescope within less than a minute. If the telescope control system is happy with the observation details requested the status flag will change to 2 and you need then only sit and wait for the observation to take place.

When you submit an observation to the queue, it is important that you supply your **username** correctly. The software will not allow you to perform observations using an unrecognised **username**. When submitting observations, the password field is used only to identify your observations later on, so that you can delete or submit them at will. It is not, and need not be, the same as the password you used to first access the **Setup Obs** page. In fact, this password field can be left blank, but that would mean any user could submit or delete your observations.

The **Show Queue** web page does not automatically update – you will need to manually refresh it by clicking on the link at top or bottom of the queue display - you should see the status to change to 2 when your observation is accepted by the telescope and then to 3 when the observation is running and finally 4 when completed and the data are available for viewing. Within about 30 seconds the observation is then moved to the **Archive List**.

You do not have to wait online for observations to complete; you can submit observations days in advance. You do not even have to be online when the observation takes place, although it might be fun to see the monitor as your observation occurs. You can simply connect back sometime later and view the resulting data. If at some point you decide you don't want a particular observation you can click on **Delete** and by supplying a password remove it from the queue. At the moment it isn't possible to remove an observation after scheduling on the telescope.

8. Setup Obs

In order to set up an observation and place it on the queue you will need to click on the **Setup Obs** link. There are detailed instructions on this page itself. Other than the obvious parameters to which we have already referred such as target coordinates and scheduling time you will also need to define a reference observation in order to correct for the response of the receiver or to subtract background emission. There are two types of reference observation:

- *Frequency-switched* observations (used generally for observations of our own Milky Way) in which the reference has the same coordinates as the source (or target) but the observing frequency is shifted by several MHz. This moves the HI emission outside the band and the reference observation therefore just defines the instrumental response which is then automatically subtracted from the source observation.
- *Position-switched* observations in which no frequency offset is made but the reference coordinates are shifted by several degrees from the target direction. This provides a spectrum of HI in a neighbouring line of sight to that to the target and when it is subtracted can be used to minimise the contribution of emission from the Milky Way when making observations of other galaxies.

9. Sequence of Events During an Observation

A single observation consists of the following sequence of events which can be followed on the monitor:

1. Just before your observation is scheduled to take place the telescope will be in the middle of repeating the observation last scheduled.
2. When the time arrives for your observation the status will switch to:
   Aborted
   Run not set
   as the scheduling system swaps to your observation.
3. Once the observing parameters are set the status will show
   Waiting
   Off source (slewing)
   Source
   as the telescope slews to your target coordinates (note difference between demanded and actual az/el - assuming previous observation was not already pointing in the direction you require).
4. When the demanded position is reached status changes to:
   Integrating
   Normal
   The observing frequency should be close to 1420.406 with a small correction due to the telescope's velocity with respect to the Local Standard of Rest (typically a few 10's of km/s) or a larger correction due to a source velocity (if set) - note a 100 km/s velocity produces a shift of about 0.5 MHz.
5. When the countdown reaches zero the calibration process begins and status will show:
   Done

    Calibrating
You should note that first the received power will increase as a calibration level from a noise diode is added in. Then it decreases as a zero level is checked.

6. The telescope will then move on to the reference position showing:
    Waiting
    Off source (slewing)
    Reference
Note the error in demanded/actual position. If this is a frequency-switched there is no actual change in position but coordinates are checked so this status will show briefly.

7. Once the telescope is happy it is pointing at the reference position then status will switch to:
    Integrating
    Normal
If this is a frequency-switched observation then the frequency will change to the previous value plus the offset (+/- 3 MHz).

8. Once the integration is complete there is a calibration process on the reference:
    Done
    Calibrating

9. The reference spectrum is then subtracted from the source spectrum and the result is returned to the web server for you to analyse.

10. This whole sequence of *(source:calibration):(reference:calibration)* will now repeat until a new observation is scheduled.