The University of Manchester
Jodrell Bank
Observatory

MANCHESTER 1824

Jodrell Bank *internet* Observatory

Introduction

The Jodrell Bank internet Observatory (JBiO) is a web interface to Jodrell Bank's 7-metre radio telescope. The telescope is fitted with a 21cm spectral line receiver. The software which handles communications between the telescope and the web server will only be running at the times designated for internet observing and displayed on the JBiO **Home** page.

In order to use the Internet Observatory you must be logged in with a username and password provided to you by Jodrell Bank Observatory.

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 in the menu bar. 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 bar 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") the web page. If this does not give recent (ie. 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 status is summarised on the "Front Page" link at the top left of this website. If you still think something should be updating and it isn't you'll need to contact whoever arranged your access to the internet observatory, it's always possible the communication software has crashed.

The only other thing that might stop observing is mechanical failure of the telescope (thankfully rare) or weather (high wind in particular).

An annotated example of the monitor screen is shown below:

Control:	Remote	What is controlling the telescope - when using the web interface this should read "Remote".
DL:	DL Allowed	If DL is allowed you can submit observations.
Time (UT):	14:07:27 7/12/2007	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:	54352	Modified Julian Date. The number of days since midnight on 17 November 1858.
Observer:	TOBR0712071400	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 i.e. in this example 14:00 on 7th December 2007.
Coord system:	Galactic		Either galactic, equatorial [J(2000)] 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:	Integrating		Either Not observing, Waiting, On Source, On reference etc
Telescope:	Normal		Either Tracking, Off source, Calibrating, etc.
Received power:	4.12		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)	1422.894		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..
Secs. remaining:	43		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: Fri Dec 7 14:07:32 2007			This is the time according to the communications software at which the monitor information was recorded.

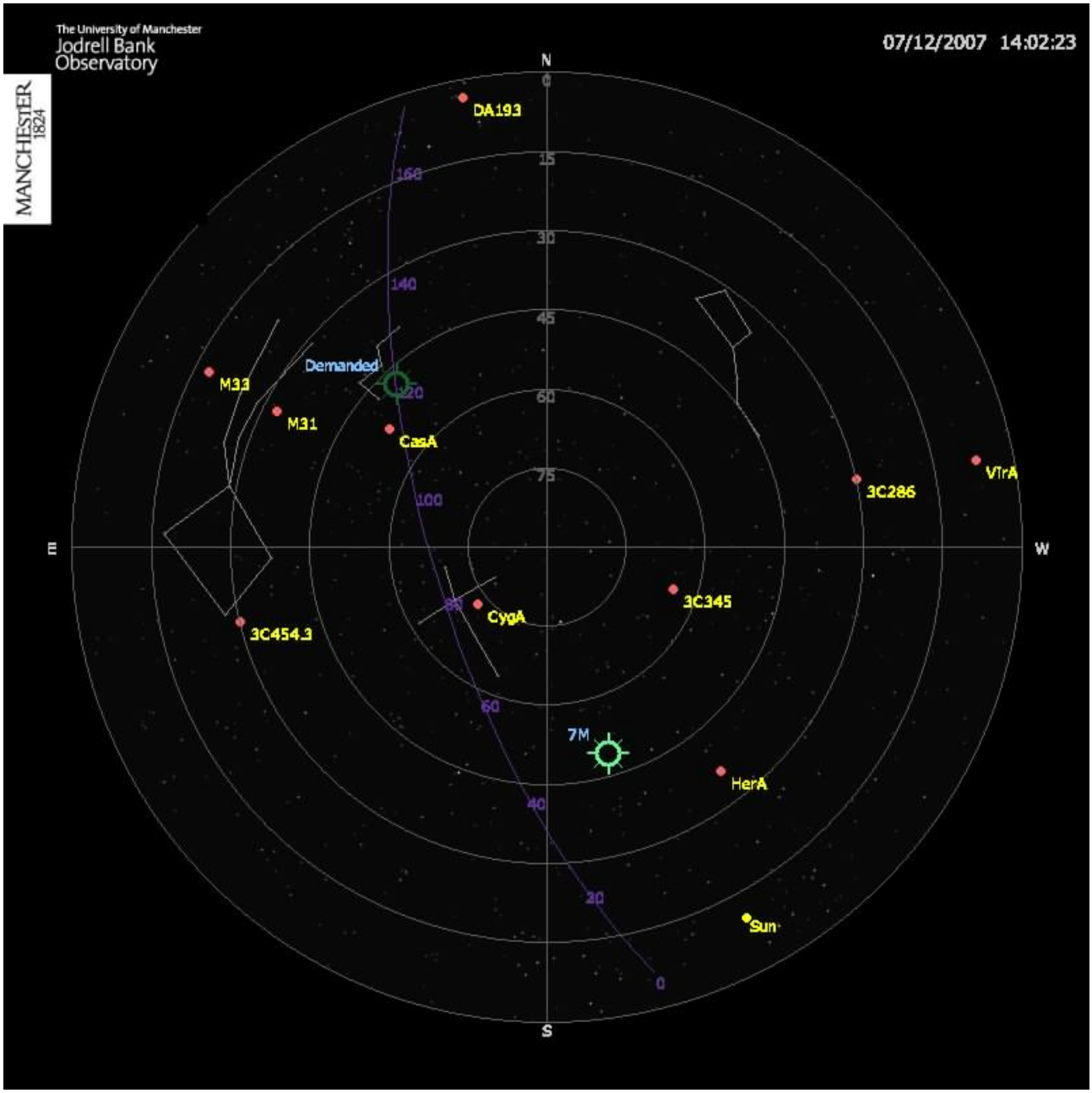
Webcam

Clicking on the **Webcam** link in the menu bar will launch a separate window in which you will get an image of the 7-metre telescope which updates every 30 seconds. The view is towards the East (approximately, i.e. 90 degrees azimuth). The date/time at which the image was taken is shown at the top of the image (in white)- 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!

Skymap

Clicking on the skymap link gives a live map of the sky above Jodrell Bank shown below.



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 latititude 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-metre 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 (as in the image shown here). The image updates automatically every 10 seconds. If the image fails to appear you can just wait 10 seconds until the next automatic refresh.

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.

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, which is one hour behind British Summer Time.
4. Set up all the details of your observation (e.g. coordinates, reference, integration time, timeslot etc) and submit to web schedule.
5. When you're happy the details of your observation are correct then 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.

Target choice

In our case we will be carrying out certain specific observations where we will be suggesting targets to you although we have built in some flexibility. 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. Hence objects directly above my head here at Jodrell Bank have declinations of about 53 degrees since that is our latitude on the Earth. 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 March 21st. [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 March 21st) objects of 6h RA will be overhead 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.

Target Track

By clicking on the **Source Track** link in the menu bar 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.

Check the elevation of a position with galactic coordinates (120,0) (i.e. longitude 120 degrees, latitude 0 degrees) for Dec 13th 2004. 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).

Schedule and 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. 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 booked a slot you were interested in using. Click on **Schedule** to display a list of all observations which have been queued for the current session. (You will need to be logged on to look at the schedule). An example is shown below:

Status	User	Submitted	Scheduled	Slots	Type	Source	Details	Submit	Delete
2	TOBR	Dec-14 14:45	2006-12-18 10:20	2	Spec	105, 10	Details	Submit	Delete

We see here that user TOBR has queued an observation. It was submitted at 14:43 on Dec 14 and is scheduled to take place at 16:00 on Dec 14th and lasting for one 10 minute slot i.e. you would be able to submit another observation to start at 16:10.

For the live version of the queue obtainable by clicking on **Schedule** you will be able to access more details of each observation by clicking on the *Details* link (if you click on the links in this page you will simply be returned to this page as this is not a live link to the queue).

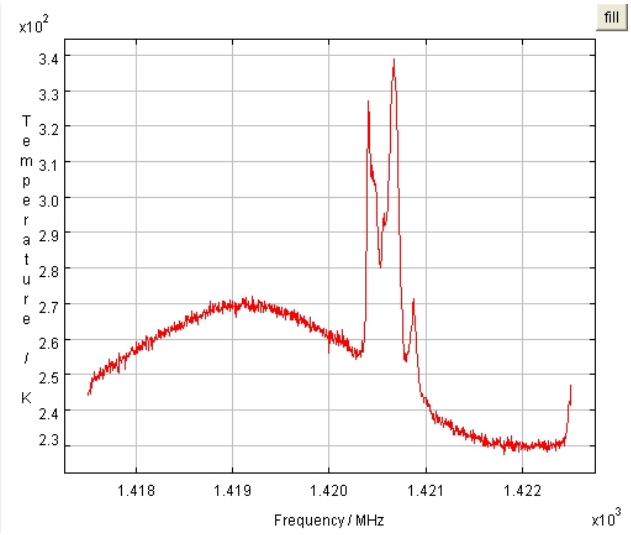
The status field can contain one of 7 numbers:
0: Observation just entered, waiting to be submitted to telescope queue.
1: Observation submitted for scheduling, waiting for confirmation from telescope scheduling software.
2: Observation now queued and waiting to be done.
3: Observation in progress.
4. Observation completed.
8: Observation rejected by telescope scheduling software - already scheduled.
9: Observation rejected by telescope scheduling software - invalid format.

Please note 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) in the list obtained by clicking on the **Archive** link on the menu bar. Here you can browse various sets of observations e.g. the most recent 20, those from the last 24 hours, even those requested by particular users.

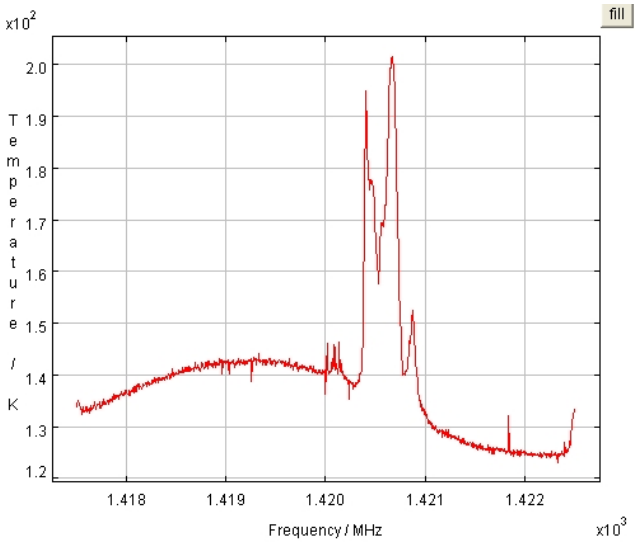
In this list data should be available for any observation by clicking on the **Data** link. Try this on the archive list for any observations with a status 4 green code. An example of the result is shown at right where plotting of the data is achieved using a java applet.



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 curving 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.

The spectrum shown above is relatively interference free. However you may occasionally see narrow spikes of interference or a pattern of spikes near to 1420 MHz as in the example at right.



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.

Observe

In order to set up an observation and place it on the queue you will need to click on the **Observe** link. There are two types of observation – a spectrum or a scan. There are detailed instructions on

each of these pages. Other than the obvious parameters to which we have already referred such as target coordinates and scheduling time in a spectrum 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:

1. *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.
2. *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.

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 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.

The **Schedule** 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.

Please note: you do not have to wait online, 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 for some reason (which should be unlikely) the telescope rejects your request the status will change to a 9 (red) code.

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.

Sequence of events during an observations

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 observer field will change to your name and time code as the scheduling system swaps to your observation.
3. Once the observing parameters are set the status will show
   Waiting
   Off 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:
   On Source
   Tracking
   The Secs. Remaining field will count down to zero.
   The observing frequency should be close to 1420 MHz with a 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:
   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 (if a slew is required, otherwise just Tracking)
   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:
   On reference
   Tracking
   The timer will again countdown to zero.
   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:
   Calibrating
9. Finally the observation status switches to
   Not observing
10. The reference spectrum is then subtracted from the source spectrum and the result is returned to the web server for you to analyse. You can find the results by looking at the archive list.

Observing programmes

Detailed scripts for the experiments for your course will be available before observations begin.