

Live Observing with the Liverpool Telescope

Wednesday 14 October 2020

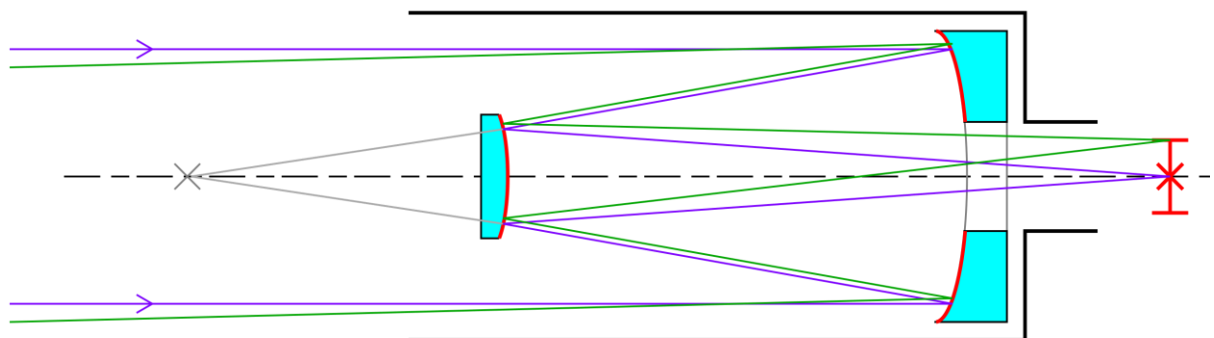
8pm – 10pm



1.1 Introduction

The Liverpool Telescope (LT) is a fully robotic telescope based at the *Observatorio del Roque de Los Muchachos* on the Canary island of La Palma, Spain. It is owned and operated by Liverpool John Moores University as an international research facility, with financial support from the Science and Technology Facilities Council (STFC).

The telescope is of a Richey-Chrétien optical design, which means it has a hyperbolic primary and secondary mirror to minimise optical aberrations. The primary mirror is 2 metres in diameter. The telescope has an array of instrumentation mounted at the Cassegrain focus (underneath the primary mirror). At the focus the light is directed to the various instrumentation via a rotating flat mirror.



Light path in a Cassegrain reflector telescope. Wikipedia/Krishnavedala

'Fully robotic' means there are no telescope staff or observers based at the observatory. Neither is the telescope 'remote control' in normal operation, with staff in Liverpool directing operations. Science users put observations into the observing queue via a web-based interface. The telescope itself has a robotic controller which is responsible for safe operation of the telescope, and will choose what and when to observe based on its scheduling algorithm. This scheduler accounts for factors such

as science priority, target altitude above the horizon and weather conditions when choosing what to observe next. Data products are available to science users within ~10 minutes of the observation being concluded, again via a web interface.

The LT is a 'common user' facility rather than a dedicated 'project', meaning it is used for a wide variety of science programmes. However, the flexibility and rapid response capabilities of robotic telescopes make them powerful tools for time domain astrophysics: the study of the changing sky. Typical science uses are follow-up of supernovae and gamma-ray bursts, observations of eclipsing binaries and transiting exoplanets, and tracking of fast-moving near-Earth objects.

For more details of the telescope and its instrumentation, see the LT website here:

<http://telescope.livjm.ac.uk/>

1.2 Live observing

On Wednesday night we will conduct a live observing session with the telescope. This will begin around sunset at 8pm BST, and last about two hours. The session will take place in the same Zoom room as the rest of the school.

Over the course of the session you will be introduced to the telescope and its capabilities. As the sky darkens we will look at the engineering interfaces and the mechanical aspects of the telescope. Then towards the end of evening twilight we will take control and make some observations. We will be looking for participants in the session to suggest objects to observe, and hopefully we will observe a mix of both 'eye candy' and objects of genuine scientific interest! All of the data will be available for you to look at in real time during the session, or analyse at a later date.

The one thing we cannot control is the weather. Conditions at the observatory are mostly excellent year-round, but in October we might expect to lose ~10-15 per cent of time to bad weather. If the weather is poor then we will have to content ourselves with looking at some data from previous nights, and putting some observations into the observing queue for the telescope to obtain on a future night.

1.3 Observational astronomy for beginners

In this section we aim to provide someone without an astronomical background with the knowledge they need to suggest suitable targets for observation.

Consider a line on the sky which passes through North on our horizon, Zenith (the point directly above our heads) and South on the horizon. This is our **local celestial meridian**. The rotation of the Earth means that over the course of 24 hours a star will rise above our eastern horizon, increasing in altitude until it **transits** our meridian, and will then decreasing in altitude until it sets below our western horizon. The path the star takes across the sky will depend on its coordinates and our latitude. At any particular point in the night therefore, an object may or may not be visible. We may have to wait until later on in the night for it to rise above our horizon. If we are unlucky it may be sufficiently close to the Sun such that it is only visible in the daytime, in which case we have to wait until a different time of year in order to observe it. It may be that it never rises above our horizon: some Southern hemisphere stars are never visible from Northern observatories, for example.

The visibility of an object depends on its **coordinates**, our **latitude** and the **local sidereal time**.

Astronomical coordinates consist of a Right Ascension and a Declination (and an equinox, but we won't worry about that here). Right Ascension (RA) is analogous to longitude on the Earth and is the angular

distance on the sky from a reference point known as the First Point of Aries. Even though it is an angle it is convenient for us to measure RA in hours, minutes and seconds. Declination (dec) is analogous to latitude on the Earth and is the angular distance from the celestial equator. It is typically measured in degrees, arcminutes and arcseconds. The declination is 0 degrees at the equator and +90 and -90 degrees at the North and South celestial poles, respectively.

For example, M1 (the Crab Nebula), has coordinates $5^{\text{h}} 34^{\text{m}} 31.94^{\text{s}}$, $+22^{\circ} 00' 52.2''$.



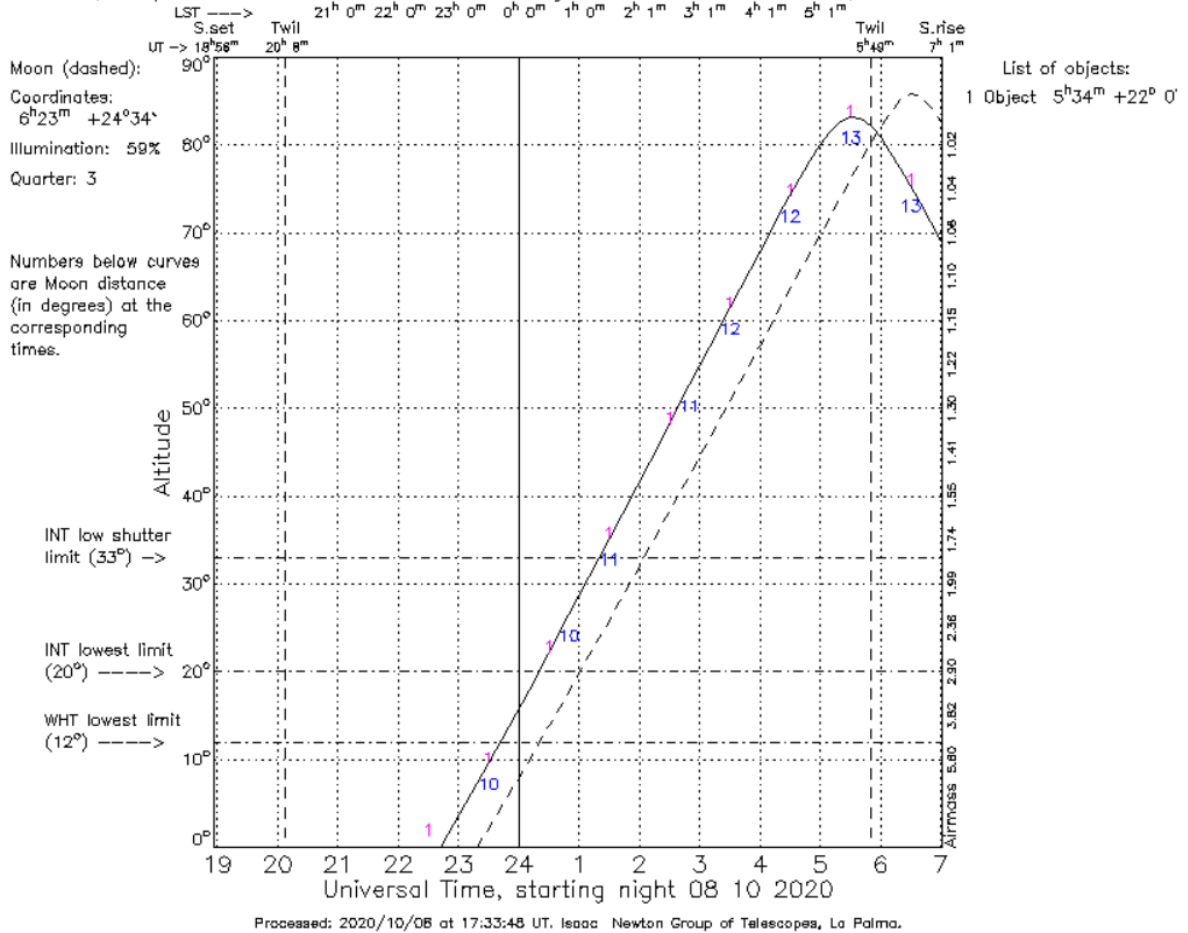
Messier Object 1: the Crab Nebula

Local Sidereal Time (LST) is 'star time' and is distinct from Solar time. If we measure a Solar day via two consecutive transits of our meridian by the Sun (noon to noon) we will find it is 24 hours long. However, if we do the same thing with a distant star we will find the day to be 4 minutes shorter. The reason is that over the course of a day the Earth has advanced ~ 1 degree in its orbit around the Sun, and so has had to rotate ~ 361 degrees to get the Sun back to the same place in the sky. The sidereal time at any particular location is easily calculated. It relates to object position in this way: a star will transit my local meridian at a sidereal time which is equal to its RA. So M1 will transit my meridian and be highest in the sky at an LST of 5 hours, 34 minutes and 31.94 seconds.

A useful tool for plotting the movement of an object across the sky can be found here: <http://catserver.ing.iac.es/staralt/index.php>

If I put the coordinates for M1 into the text field and click 'retrieve', I obtain the following plot. Note that the tool was already set to the right observatory (*Observatorio del Rocque de Los Muchachos*) and the right day of the year (tonight).

Altitudes, Roque de los Muchachos Observatory 342.1184E 28.7606N, 2326 m above sea level



This figure shows the altitude for M1 with time. We'll gloss over almost all of the information here. The solid line is the track of our object. Ignore the dashed line – that is the track of the Moon. Running along the bottom x-axis we have Universal Time in hours. This is the same as Greenwich Mean Time. Along the top of the plot in small numbers the equivalent LST is given for this particular night. Running up the y-axis on the left is the altitude of the object above the horizon, in degrees.

You can see that M1 will rise above the horizon a little after 22:30 UT. It will get higher in the sky over the course of the night, hitting its maximum altitude of ~83 degrees at about 5:30UT, or an LST of 5:34. Note that the fact that these two times are so similar is because right now we are very close to the autumnal equinox, at which UT = LST. If we were observing at the vernal equinox in March, UT and LST would be 12 hours out of sync due to the 4min drift per day.

We will be observing for the first few hours of the night, and so M1 would be a poor choice of target for us as it will be below the horizon at that time.

1.4 Choosing targets

So what are we looking for when choosing a target? We need something with an RA and dec such that it will be visible at the beginning of the night. We also need something that is bright enough for us to observe, which we haven't really touched on yet. For RA and dec you can use the tool introduced in the previous section to check on any target, but here are some rules of thumb:

- **RA:** The LST at the start of the night will be ~20:00 – 21:00, so we want to be selecting targets that are within two to three hours of that.
- **Dec:** The closer the declination of the target is to our latitude, the higher it will rise in the sky. The latitude of the observatory is 28.76 degrees North, so a target with a declination of 28.76 degrees will pass through our zenith. The closer to 28.76 degrees the better, but as a rule of thumb we want the declination to be -20 degrees or higher. The lower limit on the telescope altitude is 30 degrees above the horizon.

In terms of target brightness, it depends on what instrument we are using. Fainter targets need longer exposure times, so we will tend to prefer brighter targets so we can look at more objects in the time available. We typically use the astronomical magnitude system to describe target brightness. Confusingly under this system the smaller the number the brighter the object. For example an 11th magnitude star is 10,000 times fainter than a 1st magnitude star. In terms of imaging, the faintest we are likely to go is 20th to 21st magnitude. For spectroscopy, we will not observe objects fainter than 19th magnitude.

Places to find targets:

- For pretty pictures, the *Messier Catalogue des Nébuleuses et des Amas d'Étoiles* ("Catalogue of Nebulae and Star Clusters") is a good place to start. See the Wikipedia link here: https://en.wikipedia.org/wiki/Messier_object
- For objects of scientific interest, a good website to start with is the Astronomer's Telegram. This is a service by which astronomers can quickly bring new and interesting targets-of-opportunity to attention. <http://www.astronomerstelegam.org/>
- Another service which does much the same job is AstroNotes: <https://wis-tns.weizmann.ac.il/astronotes>
- The Transient Name Server is a more detailed and searchable database of new targets of opportunity. Candidate supernovae and the like: <https://wis-tns.weizmann.ac.il/search>

Have a play with these tools, and come to the session armed with suggestions. We'll observe as many as we have time for!

1.5 Data access

Liverpool Telescope data are all associated with a proposal ID. To access the data a password is needed. The credentials for our data are as follows:

ID: JT20A04

Password: 11079982

To access the data, you have two options. During the live session your best option is to use the LT 'Quicklook' page at <http://telescope.livjm.ac.uk/DataProd/quicklook/>. Data will appear here next to the corresponding proposal ID within about 10 minutes of being taken. You can view an image preview or download them in FITS file format (the astrophysics data standard) by clicking on the links.

After the live session, all data will be available for access at any time in our online archive at https://telescope.livjm.ac.uk/cgi-bin/lt_search. Tick 'Proposal ID' under 'Administrative Criteria', select the correct ID then click search.