

What's that moving in the sky?

Observing comets with
robotic telescopes

Metadata

General Info

Title: What's that moving in the sky?

Short description: In this exercise, students find a comet that's visible in the night sky and take images of it using the LCO robotic telescopes. Through the investigation, students become acquainted with observing, planning observations and interpreting astronomical images.

Keywords

Comet, observing, Solar System, orbits

Educational Context

Context: In this activity, students use Stellarium to find comets which are suitable to observe with the LCO robotic telescope network. They learn what a comet is, and how robotic telescopes work and how to find objects in astronomical images. At the end they discuss the importance of observing solar system objects and reflect on the methods and tools they used, presenting their results to the rest of their class.

Age: 11-18

Prerequisites: basic information about the Solar System

Lv. Of difficulty

Aggregation Level

Duration :2-3hrs

Educational Objective

Cognitive Objectives

- To learn about our Solar System and comets specifically
- To learn about robotic telescopes
- To learn about the night sky

Affective

- To understand how different objects are visible at different times of the night/year from specific locations
- To understand how robotic telescopes work
- To understand what comets are and how they are observed on Earth
- To understand what astronomical images show

Psychomotor

- To be able to use specific software to plan observing sessions on robotic telescopes
- To be able to use robotic telescopes to observe specific objects
- To be able to identify comets in astronomical images

Subject Domain

Big Ideas of Science

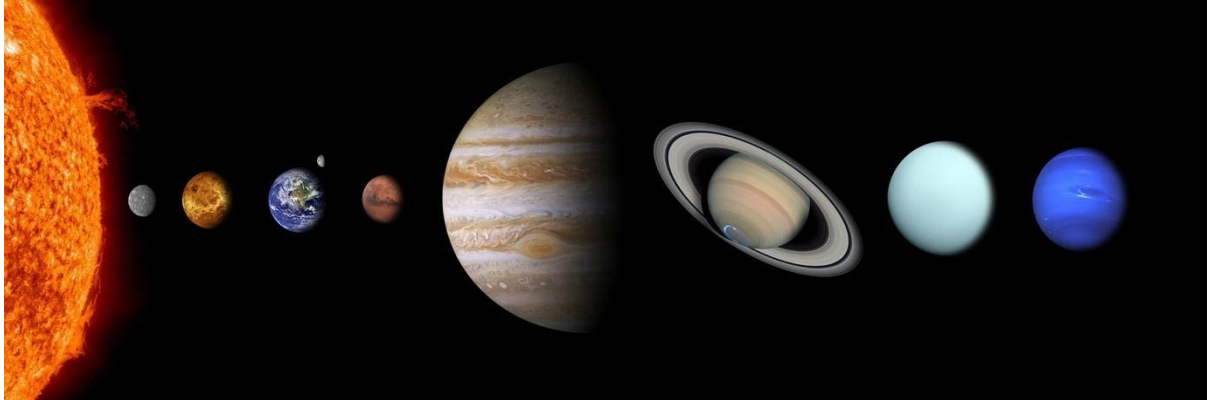
The Solar System is a very small part of one of millions of galaxies in the Universe.

Subject Domain

Physics, Astronomy

Orienting & Asking Questions

Our Solar System consists of a central star, which we call the Sun, orbited by 8 planets (can you name them?), 5 dwarf planets and millions of asteroids and comets. The image below is an artist's impression of the Solar System, showing the location of the planets and Sun in our Solar System (this is NOT drawn to scale!):



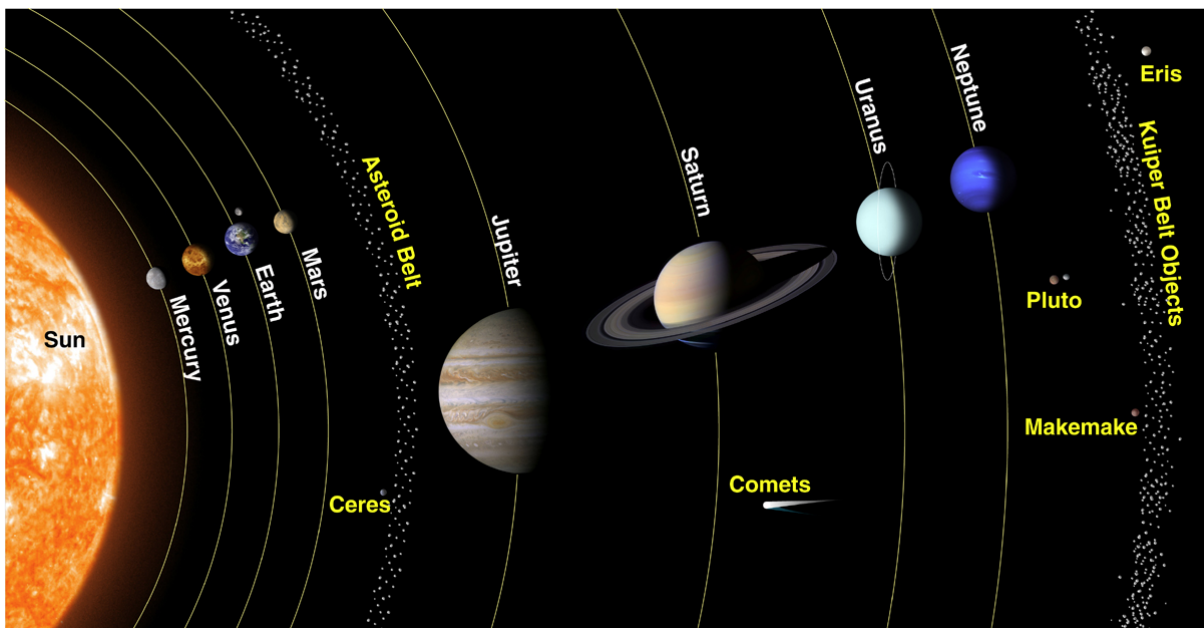
Can you think of a sentence which helps you remember the names and order of the planets?

One example is:

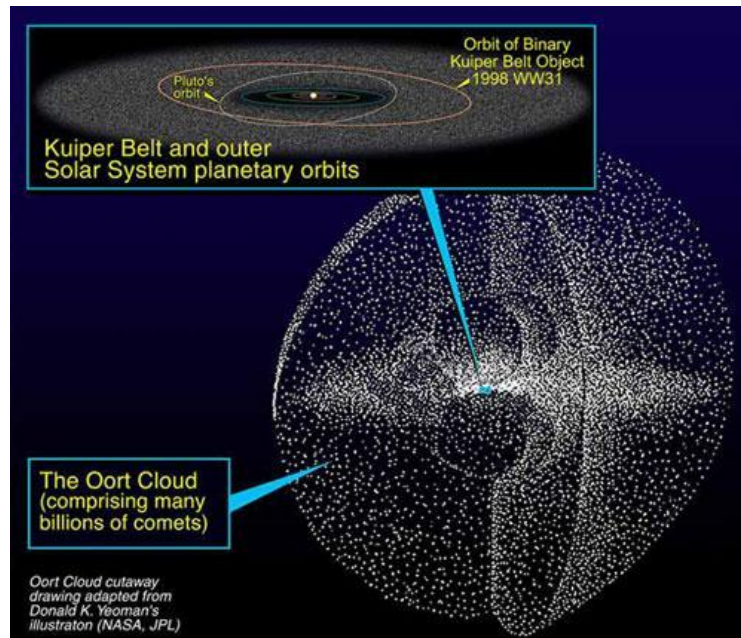
My Very Energetic Mother Just Served Us Noodles ☺

(Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune)

Actually, our Solar System contains more than just the Sun and the planets and is better shown in the image below:



This picture shows the Sun, planets, dwarf planets and also the position of the asteroid belt (between Mars and Jupiter), and the Kuiper Belt – this is where some of the comets which pass by the Earth, come from – the other place is the Oort cloud. If we zoom out of the picture above, then we can see the Oort cloud – this is seen in the picture below.

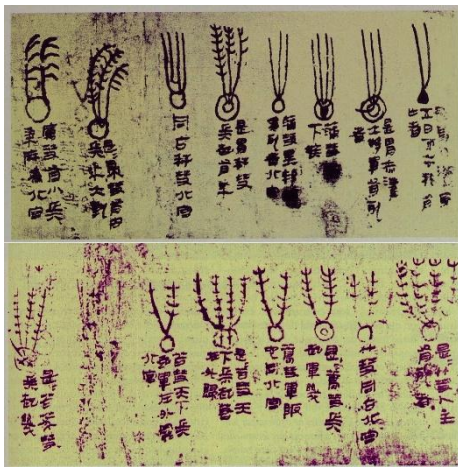


The Oort cloud contains billions of comets, and we will now look into more detail of what comets are and how we can find and observe them below.

Comets in history

The name 'comet' comes from the Greek word **kometes** meaning **hair**. Comets were seen as hairy stars. In the past comets were seen as mysterious objects which suddenly appeared and were thought to bring catastrophe!

This meant that they were closely studied to try to predict when they would appear, so rulers could try to avoid catastrophes. These observations, over thousands of years, have proved very useful in identifying returning comets.



Source: Wikimedia Commons

The 1066 appearance (known as an apparition) of Comet Halley was shown in the Bayeux Tapestry - and that certainly was a year of catastrophe for King Harold! Older observations of Comet Halley and other comets were made by the Chinese as long ago as 240 BC! In 1705 Edmond Halley predicted the return in 1758 of a particular comet. His analysis of older records of comets had shown that there was a pattern of around 76 years. Unfortunately he did not live long enough to be proved correct and see the comet that now bears his name return in 1758. Halley's careful observations and analysis, along with others such as Tycho Brahe, proved that comets were outside our atmosphere and travelled great distances in their orbit of the Sun.

Comets important now

You might wonder why we still study comets. The answer is that they contain clues to answer the big questions of How did the solar system form? What were the original ingredients? How did water and life get to Earth? Did they get to other planets too? Also, tracking comets is very important to try to mitigate any future risk of impact – a comet impact is a possible cause for the extinction event that killed the dinosaurs, and any future impact would have serious consequences for the future of life on Earth. If you'd like to investigate impacts on Earth, take a look at the LaSciL demonstrator, 'Don't Look Up!'

Make up of a Comet

There are three basic parts to a comet:

- a. the nucleus
- b. the coma
- c. the tails



Fig 1: Comet Hale-Bopp
photo by Elizabeth Warner

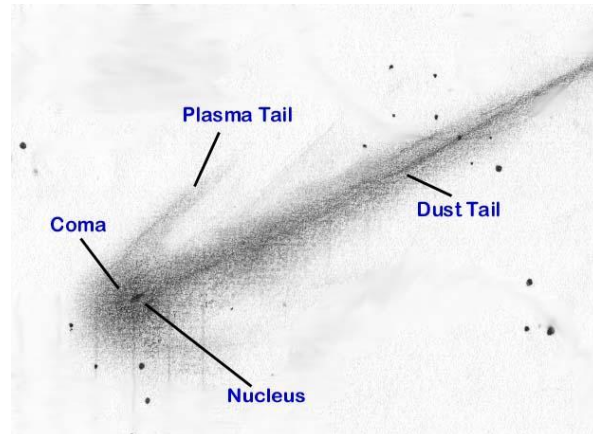
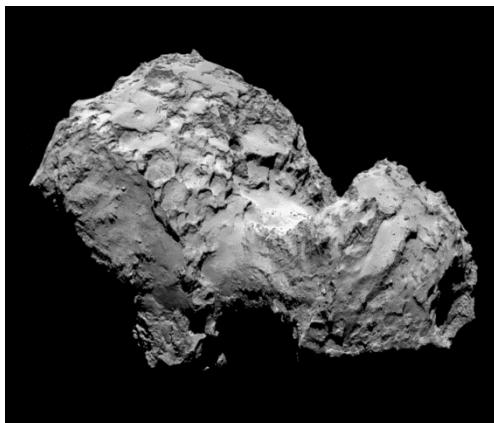


Fig 2: Drawing by W.D. Ferris

Comet Nucleus

The innermost region of the comet is known as the nucleus. It is very hard to directly observe as it is very dark and does not reflect much light. When the early space missions to a comet made close up observations of Comet Halley they found it was a solid structure (rather than just a collection of particles) and was as dark as printer toner. More recently, the Rosetta Mission to comet 67P has studied a nucleus in much greater detail and over a longer timescale. The surface is harder than expected – which is why the lander Philae bounced on landing and then could not drill into the surface. The composition is considered to be a hard crust of dust, with some smaller loose particles. Below the surface is a porous (many holes) mix of dust and different types of ices. There are cavities below the surface, and holes, indentations, cracks and cliffs on the surface. Perhaps the most surprising thing though was the shape – like a duck! - leading to a theory that the comet was once two objects which slowly collided and stuck together.



On August 3, 2014, Rosetta, the first spacecraft to visit a comet, took some of its first pictures of the duck-shaped object.
Photo: ESA, Rosetta/MPS for OSIRIS Team MPS, UPD, LAM, IAA, SSO, INTA, UPM, DASP, IDA

Like Earth, a comet nucleus rotates as it travels through space. Scientists try to find out the rotation period (a comet 'day') and the axis of rotation. This is important as it affects which parts of the comet get most sunlight and influences how active the comet becomes.

Comet Coma

The coma is a huge cloud of dust and gas surrounding the nucleus. Most of the gas comes from ices which have sublimated (having gone from the solid phase to the gas phase skipping the liquid phase) from the nucleus. As we usually cannot test a comet nucleus directly, we analyse the coma and seek to draw conclusions about the make-up of the nucleus from the gas and dust emitted.

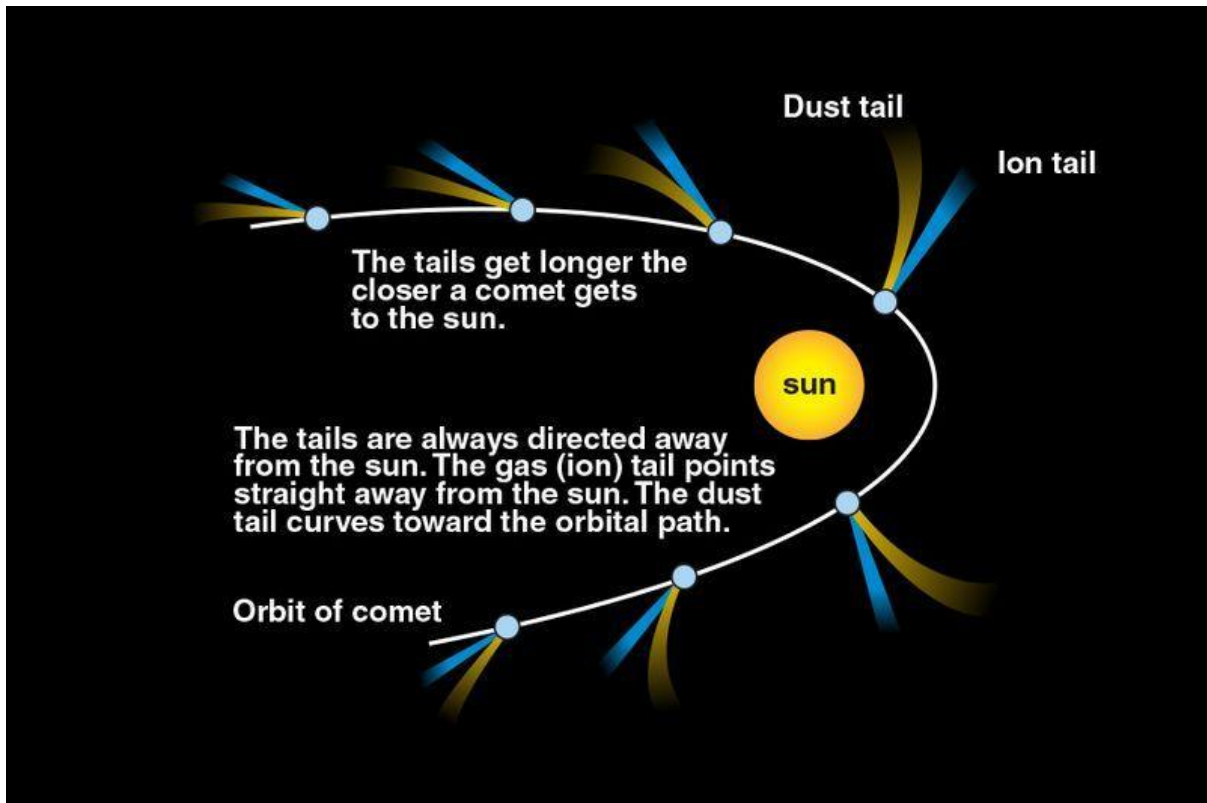
While the nucleus of a comet may only be a few to a couple tens of kilometres in diameter, the coma can extend for hundreds of thousands of kilometres. The coma changes in both brightness and shape through a comet's orbit. Different elements come into play at different times. Generally the coma is smaller and less bright when the comet is a long way from the sun. As it gets close to the sun and more gas and dust is emitted it gets brighter and bigger. This is not necessarily a smooth process though. There may be outbursts from cracks and features on the surface (even cryo(ice)-volcanoes) which cause a big jump in brightness and size. Large outburst can be detected from Earth – we want observers to look for these and alert us. These outbursts can form jets and arcs and make the coma very asymmetrical. This in turn can allow us to detect rotation and spin effects.

By considering the colour of the coma we can detect dust (red filter) and gas (blue or CN filter) features and relative abundances.

So analysing the coma is very useful.

Comet Tails

A comet, while close to the sun, usually has two tails. One is made primarily of gas and always points away from the sun. This can look pretty weird since sometimes this tail can be in front of the comet as the comet heads away from the sun along its orbit. The other tail is made of dust that is left behind like a trail of crumbs. If a comet has an orbit that occasionally crosses the Earth's orbit, we might pass through that trail and have a meteor shower.

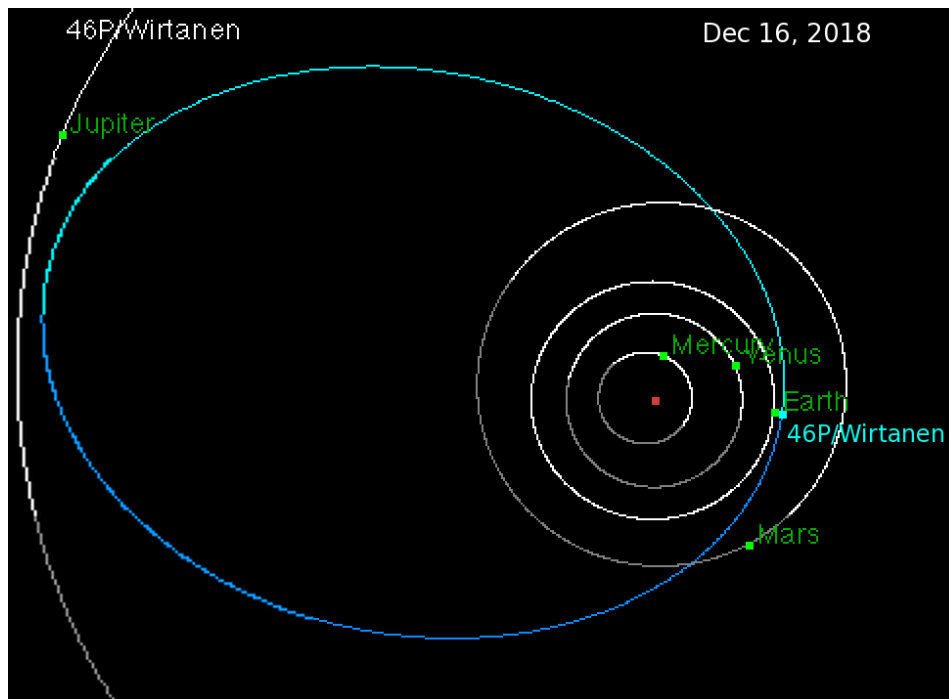


Studying comet tails tells not only things about the comet but also about the solar wind. This is material which comes from the Sun and travels at high speed. The Solar wind affects the shape of the coma, but its most dramatic effect can be seen when it encounters a comet's tail, we can see and study the results.

Comet Orbits

Comets, like the planets, orbit around the sun. But the orbits of comets tend to be much more elliptical (oval or egg-shaped).

This is the orbit of Comet 46P:



An interactive version of the orbit can be found here

<https://ssd.jpl.nasa.gov/sbdb.cgi?sstr=46p;old=0;orb=1;cov=0;log=0;cad=0#orb>

On this site you will be able to see where the comet is in the solar system at any time, run its orbit at many times actual speed, and also view it from various angles. You can easily also choose a different comet – Halley would be a good one - to compare orbits.

Different comets have different orbits as shown in this animation

<https://www.youtube.com/watch?v=7l16fVKKURs>

What do comets look like in the sky?

Remember their name? - long-haired (star). That's basically what a comet looks like in the sky -- a fuzzy spot possibly with streams of light coming from it. But each comet is unique in appearance. They differ in size, shape, colour, and length and shape of tail. They also change in appearance as they travel in their orbit around the Sun. Generally, they become more active as they get closer to the Sun. This means they get brighter, bigger, and their tails get longer.



Fig 1: The Mawangdui silk, a 'textbook' of cometary forms and the various disasters associated with them, was compiled sometime around 300 BC, but the knowledge it encompasses is believed to date as far back as 1500 BC.

Astronomical Images

There are 2 important related factors to consider when imaging an object in the night sky – how bright the object is that you are observing – this is known as the **magnitude** of the object. In astronomy, magnitudes work backwards! What does this mean? Well, a lower number for the magnitude means that the object is brighter....let's see if we understand this. Which is brighter, a star of magnitude 7 or a star of magnitude 1? Since 1 is a lower number than 7, a magnitude 1 object is brighter than a magnitude 7 object, so in this case the star of magnitude 1 is brighter!

The other important factor to consider when imaging an object in the night sky is how long you should image the object for – this is known as **the exposure time** and is a measure of how long the camera's shutter is open for in the telescope, thus how long it collects light to form the image of the object being observed.

If an object is very bright then you don't have to look at it for a long time with a telescope before you get a good image (thus you use a short exposure time), If it's quite faint however, then you will need a longer exposure time to ensure that you collect enough light from it to make a good image.

There are actually other factors to consider when using robotic telescopes to observe, such as the size of the telescope (i.e. how big the main mirror is – the larger the mirror, the more light it collects and therefore the better the image), and the atmospheric conditions – is it cloudy, or high humidity? Is the Moon up in the sky at the same time as the object we are observing? If so, what phase is it in? You may have noticed that when the moon is full, the sky becomes quite bright, and fainter objects in the sky become much harder to see. When we are using telescopes and the moon is full, a lot of the scattered moonlight can appear in our astronomical images, which ‘washes out’ our the light from our actual target and making our image quality not as good as we’d like it to be. We can minimize this effect by using a red filter to observe our objects (as moonlight scatters more at blue wavelengths, so red images are less affected).

Observing comets

So how do we find comets in the night sky and how do we observe them with the LCO robotic telescopes?

In order to do our investigation, we will use the website, “Heavens-Above” to find suitable comets to observe with the LCO telescopes and plan what we will observe, and then we will use the “queue” mode observing method of the LCO telescopes to carry out our observations and image a comet. Then we will learn how to identify a comet from telescope images.

Instructions on how to use Heavens above can be found in the LaSciL toolbox.

You should familiarize yourself with Heavens Above before running your investigation so that you know how to change the location of your observing site, the time/date of your observing session and how to find specific objects i.e comets, that are observable at that time/date/location.

Instructions on how to use the queue mode observing function of the LCO telescopes can also be found in the LaSciL toolbox.

You should set up an account on the LCO telescopes via the Faulkes Telescope Project and familiarize yourself with the LCO observing interface before carrying out this investigation.

Hypothesis Generation and Design

Generation of Hypotheses or Preliminary Explanations

In this activity you are exploring comets and observing them using the LCO robotic telescope network. But what do we need to think about to help us do this?

Here are some questions to think about to start:

- How will I find comets which are observable with the LCO telescopes?
- How bright should the comets be?
- How will I identify the comet in the image?
- What is the best filter and exposure time to use when observing comets?

Take some time to think about possible questions that you might like to answer and how this may form a hypothesis.

An example hypothesis should contain a statement and then an explanation. For example, one hypothesis could be:

Comets orbit the Sun in our Solar System and they can be imaged using robotic telescopes. Since they are moving objects, they are not always visible to us on the Earth. They are also quite faint objects so we have to collect a lot of light from them in order to see them in astronomical images. I hypothesize that taking a long exposure image of a comet with the LCO telescopes will give a good image of a comet. I hypothesize that the longer the exposure time, the more light I'm collecting, so the better the image. I will be able to identify the comet in an image by looking for a white spot with a fuzzy tail, or a fuzzy 'envelope' around it. To test my hypothesis, I will use 'Heavens Above' to find comets which are currently visible in the night sky, and I will take a series of images of one of them (I will start by observing the brightest comet), with increasing exposure time. I will keep all other factors the same (e.g. telescope size and filter choice). I will see if increasing the exposure time increases the quality of the image and makes the comet easier to see.

The above is a simple example, but starting off simple is a good idea, so let's try it now.

Planning and Investigating

Plan Investigation

Think of the question you want to answer - you should have written this down and thought about how you can test this (i.e. what parameters will you keep the same in your observation and what will you change?)

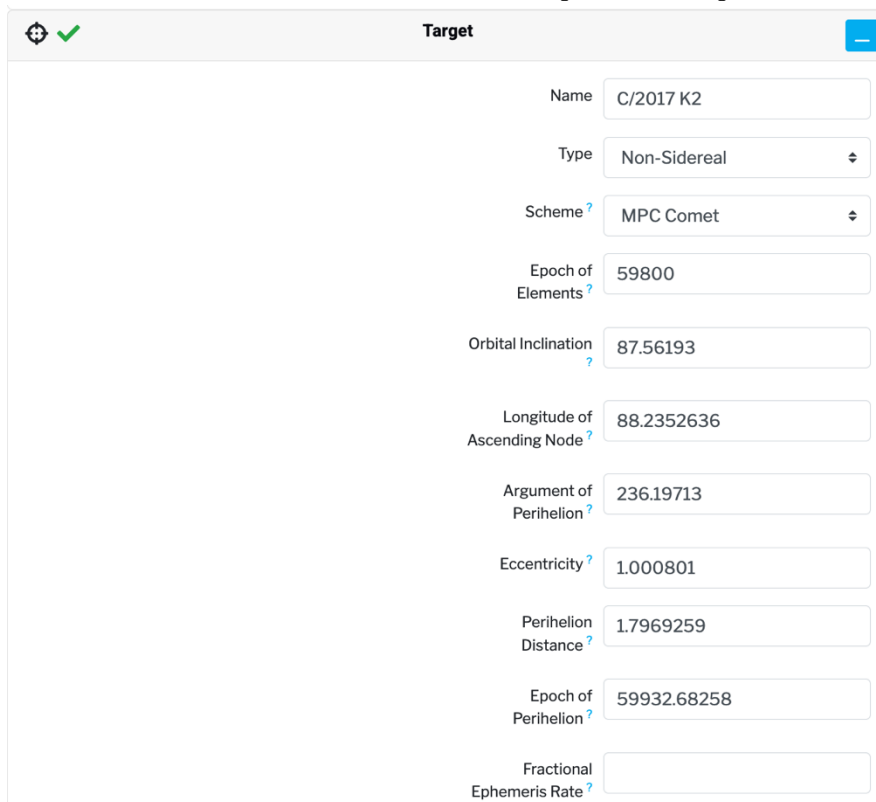
For example, if you were investigating how the exposure time of an observation affects the quality of the image, you might want to think about the questions below:

- a) How would you plan to do this?
- b) What parameters would you change and what would you keep the same in the LCO queue mode interface?
- c) For the parameter(s) that you would change, what increments would you use (i.e. in steps of 1, 2, 5, 10 etc.)?
- d) What will you record? (*hint: think about what you are investigating*). Would it be useful to create a table to record your results?

Perform Investigation

1. Open Heavens Above and find a comet that is suitable to observe from one of the LCO telescope sites. Make a note of its name and magnitude. It would also be useful to save the “fine finder chart” of the comet – this is a map of where the comet is in the sky at the specified time and date. This will help you find the comet in your image once they have been taken by the LCO telescopes.
2. Log into the LCO telescope network and make sure that your account is set to advanced mode – go to your profile once you log in and **unselect** ‘Basic Mode’ from the options.
3. Next, input the parameters of your observations into the interface. You can leave most of the parameters of the interface as their default values, but you will be choosing the size of the telescope to use, the exposure time, and the filter. If you are using the 2m Muscat camera then this camera automatically takes images with 4 filters (g,r,i,z) so you just have to put the relevant exposure time in each box.
4. As shown in image 1, input the name of the comet into the Target name section – in the example below, the comet is called C/2017 K2 PANSTARRS – however, the LCO interface doesn’t recognise this name, so only the first part is input – C/2017 K2. The type is set to ‘**Non-sidereal**’ – this means that it does not move along with the background stars. The scheme is set to ‘**MPC comet**’ and then the following boxes are filled automatically – the LCO interface searches the Minor Planet Centre (MPC) comet

database to find the necessary information about the orbit of the comet to auto-fill in these details, and this is what will help the telescopes understand where to point.



The image shows a web interface titled "Target" with a header bar containing a green checkmark icon and a blue minus icon. The main content area is a form for entering comet data. The fields and their values are as follows:

Field	Value
Name	C/2017 K2
Type	Non-Sidereal
Scheme?	MPC Comet
Epoch of Elements?	59800
Orbital Inclination?	87.56193
Longitude of Ascending Node?	88.2352636
Argument of Perihelion?	236.19713
Eccentricity?	1.000801
Perihelion Distance?	1.7969259
Epoch of Perihelion?	59932.68258
Fractional Ephemeris Rate?	

Image 1 – how to fill in the ‘Target’ section of the LCO interface when observing comets.

5. Next, choose your observing window – that is, when do you want the telescopes to try and observe your comet and when should they stop trying? In the example shown in image 2 below , we have set a time window of 2 days.

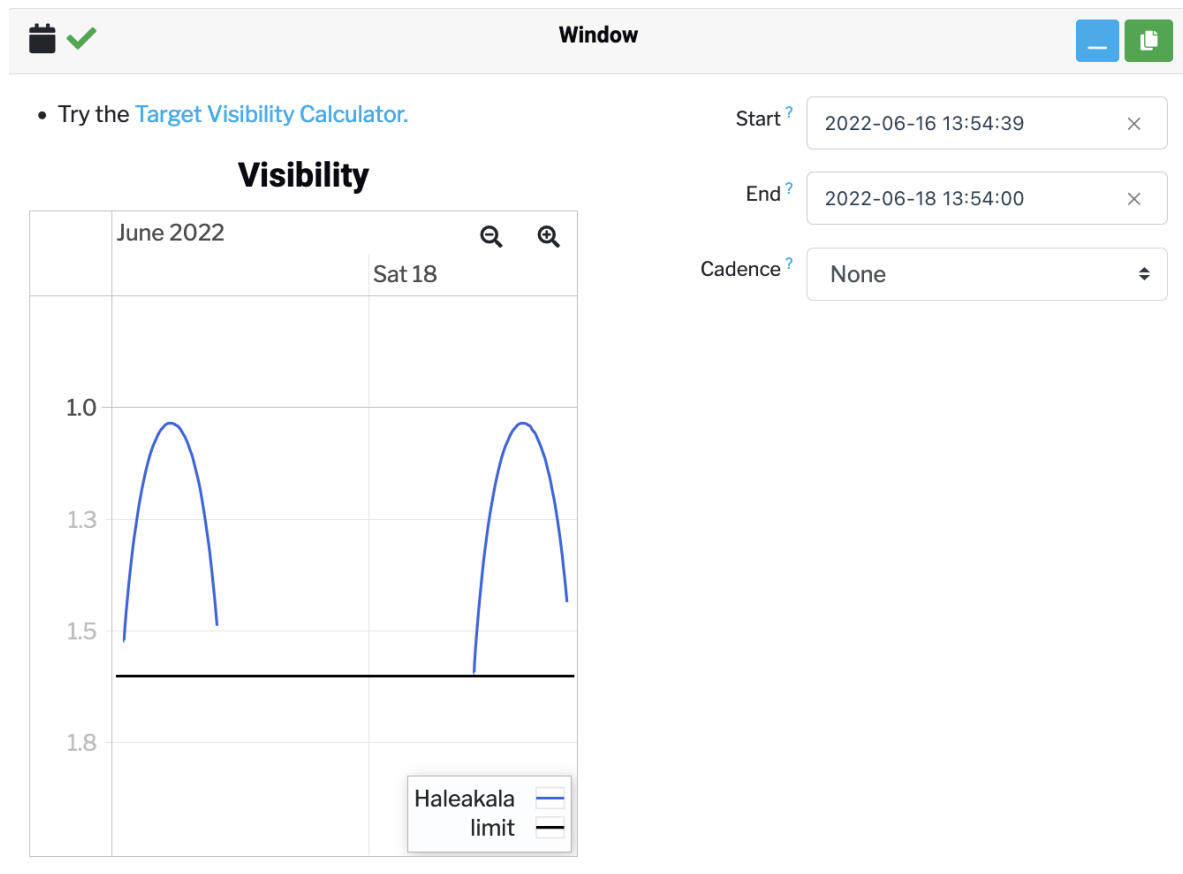


Image 2 – setting a time window of 2 days for observations.

Once you are happy that you have filled out all the necessary information you can click '**Submit Observation**' and your request will be placed in a queue for observing. Remember, if you are investigating how exposure time changes the quality of the image, you will want to submit observation requests with all the same parameters, but a different exposure time each time (according to what increments you have planned e.. 5s, 10s, 30s, 60, 90s) so make sure you submit observation requests for each exposure time.

Analysis & Interpretation

When your observation requests have been successful then you should receive an email to let you know that your images have been taken. You can view and download your images from your home screen when you log into the LCO observing portal.

Click on the greyscale image of your comet in the 'Data' tab of the results screen – it will open up in a larger window and from here you can download a .jpg version of the image.

Open up all your images – make sure you know which one corresponds to what exposure time. How do your images fit with your hypothesis? In the example above we hypothesized that a longer exposure time would give a better quality image – is this true? Is the comet easy to

identify in the images? *Can* you identify the comet? If you need help finding the 'fuzzy' blob, then remember you can use the finder chart which you downloaded from Heavens Above to help pinpoint where it is.

What conclusions can you draw about how observing parameters affect the quality of images obtained from robotic telescopes? How does a change in exposure time affect the images?

Conclusion & Evaluation

Conclude and communicate result/explanation

An important part of the scientific process is to communicate your results. Put together a poster or presentation that summarises and displays your methodology, results (including images) and conclusions of the activity.

At this point you might want to look at the various images that astronomers have obtained of comets around the world and how they differ or are similar to yours. A good place to start is this online article about the greatest comets of recent times:

<https://www.skyatnightmagazine.com/space-science/greatest-comets-of-recent-times/>

You could also think about the following:

Did your conclusions match your predictions at the beginning?

What other investigations could you do? What else could you change?

What else might influence the quality of astronomical images? Are there things which are out of your control?

Explain why astronomers study comets and what they can tell us, and how you can identify comets in images. Include any discussions that took place in your classroom or from background research that you carried out.

Evaluation/Reflection

Comment on how well your investigation went. Does it have any limitations? If you were to repeat this investigation, how would you improve it?

- Share your results with others in the class.
- Comment on any similarities/differences between your results and others.

- Think about how you individually carried out the activity and what you might change in future investigations which may affect your results.