Presentation Notes for Telescopes through the Ages

1. **Telescopes through the Ages with I-LOFAR.**

2. **What light can we capture?**

Traditional telescopes observe visible light, known as optical telescopes. They are the most well-known.
We now understand a lot more about different types of light, and can build telescopes to observe all parts of the electromagnetic spectrum, allowing us to understand more about space and the Universe.

3. **Nearly 200 years of astronomical research in Birr…**

How has our view of space changed throughout history?

4. **Whirlpool Galaxy images**

Examples of the same object, then and now. The first is a sketch from the Leviathan telescope in Birr in 1845, the second a photography taken by the Hubble Space Telescope in 2005. *Note: You may not wish to go into these details with the students yet, will be discussed in more detail later.*
Notice improvements in resolution and detail.

5. **Images from telescopes**

In small groups (approx. 5-6 students) give the students print outs of the images (printable versions provided in PDF format separately) and get them to arrange them in chronological order.
The images are from 1840s to current. We have not provided all of the information on each image (how far away it is, how large the object is, etc) so allowing for inquiry based learning and exploring data analysis techniques with the limited information they do have.

- Understanding how scientists work
- Analysing available data and working with peers
- Seeing how much the images have changed over less than 200 years

Observe the groups, most will begin to arrange the black and white images first, etc.

6. **Timeline answers**

Encourage discussion – did any groups get them all correct/close to all correct? Anything you notice? Trends – black & white to colour, first two are drawings the rest are photographs. Some of the more recent ones may look lower resolution but they may be further away object, such as 2013.
Any similarities?

1845, 1902 & 2005 are all the same object, the Whirlpool Galaxy.
1850 & 2014 are both the Triangulum Galaxy
1900 & 1922 are the Andromeda Galaxy
1964 & 1971 are the same supernova
1990 & 2018 are both the galaxy M100

7. **Details on telescope images 1-5**

1845 William Parsons drawing of M51, the Whirlpool Galaxy as observed through the 72-inch (1.8 m) Leviathan Telescope in Birr – 23.16 million light years away

1850 Drawing of M33, the Triangulum spiral galaxy, created by R.J. Mitchell based on observations by William Parsons with the Leviathan Telescope in Birr, around 1850 – 2.7 million light years away

1883 Photo of the Orion Nebula by A. A. Common with a 36-inch (0.9 m) telescope in the UK – 1,344 light years away

1900 Andromeda Galaxy, Yerkes Observatory USA around 1900 – 2.5 million light years away

8. **Details on telescope images 6-10**

1902 Photo of the Whirlpool Galaxy, M51 taken in Yerkes Observatory USA on June 3, 1902

1920-22 Andromeda Galaxy, through the 100-inch (2.5 m) Hooker Telescope USA by Edwin Hubble

1964 supernova using the 200-inch (5.1 m) Hale telescope at Palomar Observatory, USA in 1964

1971 supernova using the 200-inch (5.1 m) Hale telescope at Palomar Observatory, USA in 1971

1985 Nebula N81 in Small Magellanic Cloud obtained at the ESO (European Southern Observatory) 3.6 m telescope in Chile, November 1985 – 200,000 light years away

1990s nearby galaxy M100 is viewed in the early 1990s with Hubble Space Telescope, 94.5-inches (2.4 m) - 55 million light years away

9. **Details on telescope images 11-15**

2005 Whirlpool Galaxy, M51 by Hubble Space Telescope, released 25 April 2005

2013 Hubble Ultra Deep Field by NASA with the Hubble Space Telescope, taken/released in 2013-2014 – shows a large number of objects, many of these are other galaxies. You can make out some spiral structures.

2014 Triangulum Galaxy, also known as M33, taken with the ESO VLT (Very Large Telescope) Survey Telescope 2011-2014 – 2.7 million light years away (same object in 1850 image)

2018 Nearby galaxy M100 is viewed in 2018 with Hubble Space Telescope (same object in 1990 image)

2019 The Southern Crab Nebula by Hubble Space Telescope, 18 April 2019 – 6,849 light years away

10. Comparing images

How has our view of space changed throughout history? Ask the students to explain differences/improvements seen in the images.
Clearer pictures allow us to see the Universe in more detail and begin to understand it better. For example, in 1840s (around the time of the first image) we thought everything we could see was part of our galaxy and that here was just one galaxy. Many objects were classed as nebula as we could only se cloudy blobs of light. Better telescopes allowed us to see in more details, such as the Whirlpool Galaxy (originally called the Whirlpool Nebula) where we can see clear patches of light and dark in a spiral structure. We now know there are many galaxies, estimates of 100 billion but that will probably increase as we learn more!

11. How can we make better telescopes?

Things to consider:
- Materials
- Size
- Magnification capabilities
- Longevity & maintenance
- Position
- Type of EM radiation – all the images we have been looking at are with optical telescopes. We also use other types of telescopes observing different parts of the EM spectrum (radio, IR, UV, x-ray, gamma ray, etc) to get a clearer picture and understanding of the Universe.
  More detail on this in the '*Radio Astronomy in Birr*' lesson resources.

12. How can we make better telescopes? (continued)

Materials can be made more reflective, stronger and requiring less upkeep.
A bigger aperture (diameter of telescope) allows us to see further and in more detail. What are the advantages/disadvantages to building them on the ground vs out in space? Consider atmosphere, clouds, light pollutions, difficulty of launching/building in space.

13. How can we make better telescopes? (continued)

Can we just keep making bigger and bigger telescopes?
What might be possible issues with this?
Cost, maintenance, is there a limit to the size, or a point at which a telescope is too big? Why?

14. Some telescopes we use today

Top image: The world's largest single-aperture optical telescope is Gran Telescopio Canarias on La Palma, in the Canaries, Spain, built in 2009. It has a 10.4 m aperture.

Bottom image: FAST (Five-hundred-meter Aperture Spherical radio Telescope) a radio telescope in Guizhou, China. It has a 500 m diameter dish and is built into a basin/natural depression in the landscape for support.

15. Physical Limitations

After the collapse of a 91.4 m radio telescope in Green Bank, West Virginia, USA.
Beyond a certain size, we can only have stationary telescopes which limits the accuracy and scope of what we can study.
Singular stationary radio telescopes are confined by gravity but what about using multiple telescopes in tandem?

16. Telescopes we use today

Hubble Space Telescope, orbiting Earth since 1990. Observes from infrared to ultraviolet, so through the entire visible spectrum, It is responsible for many of the amazing photographs of space we have.
Advantages to having a telescope in space:

- No effects form the Earth's atmosphere blocking some types of light
- No effects of weather (clouds, etc)

Disadvantages:

- Expensive to launch/put in place
- Difficult to maintain – this is orbiting Earth, so it has had maintenance and upgrade missions since being launched

Any others the class can think of for discussion?

17. Telescopes we use today (continued)

The telescopes which linked together to create the Event Horizon Telescope.
Combining date from radio telescopes in these locations all around the worlds allowed us to create the largest ever telescope array, effectively making a telescope the size of the Earth.
This is a solution to some of the challenges for building telescopes larger and larger – we can link multiples in an array which then act as large telescopes.

18. Telescopes we use today (continued)

Event Horizon Telescope (EHT)

19. Telescopes we use today (continued)

The size of the EHT allowed us to take an image of a black hole at the centre of another galaxy, M87, 53.49 million light years away. This was in 2019 and was the first time we ever took a picture of a black hole.

20. Current Astronomy in Ireland

Ireland is involved in international telescopes such as those at ESO (European Southern Observatory), EST (European Solar Telescope), JWST (James Webb Space Telescope) and more.
We also have a strong history of astronomy. In Birr, Offaly, within 300 m there are two excellent examples of telescopes from different periods of time - the Leviathan Telescope from the 1840s, and the modern day I-LOFAR completed in 2017.
The Leviathan allowed the discovery of the spiral nature of the Whirlpool Galaxy which is the first of the timeline pictures.
I-LOFAR (Irish Low Frequency Array) is Ireland's largest radio telescope. It is an array of small antennas and, similarly to the Event Horizon Telescope, links up with other stations to create a large telescope.
The international LOFAR Telescope stretches across Europe, spanning over 2,000 km to create a telescope the equivalent of the size of Europe and achieving much more than would be possible for a single telescope.

21. Future Telescopes

What new telescopes are planned for the near future?

22. JWST

The James Webb Space Telescope (JWST) is now completed and is planned to be launched into space in 2021.

23. JWST (continued)

This is the primary mirror for the JWST, the aperture size is 6.5 m. It is and infrared telescope and will add to the works of Hubble Space Telescope as well as being able to look further away and help to understand the early Universe.

24. ELT

This is an impression of the European Extremely Large Telescope (ELT), which will be built in Chile by ESO, the European Southern Observatory (which Ireland is a member of). It is currently being built and the plan is to have it operational in 2025. It will be the largest single aperture optical telescope in the world, with an aperture of 39.3 m, made up of nearly 800 hexagonal mirror segments.

25. What's next?

Seeing the difference in less than 200 years, when we went from a sketch with the Leviathan telescope, to the Hubble Space Telescope and amazing images we get form it, to the new JWST and ELT, can you imagine what we might achieve in another 200 years?

Start a discussion with the students getting them to really push the limits of their creativity and imagine what telescopes of the future could be like. A possible add on is to get them to design a future telescope, individually or in groups.
Is it in space/on Earth/on the Moon/where else?
Is it optical? Or radio? Or another part of the EM spectrum? Why?
There are no limits here – do you think the astronomers in 1840s using the Leviathan in Birr could have imagined what out telescopes are capable of now?