



## Evolution of the Universe 2: The *SPIRIT* telescopes

### Components

	NAME	DESCRIPTION	AUDIENCE
	<i>The SPIRIT telescopes</i> teachers guide	This guide explains how to use the <i>SPIRIT</i> telescopes. It includes question and discussion points to support students' investigations, and a target list of deep sky objects for students to select and image.	teachers
	<i>Deep sky objects</i> background sheet	This background sheet provides information on deep sky objects, including open clusters, globular clusters, nebulae and galaxies. It also includes tips on how to obtain the best images of deep sky objects with the <i>SPIRIT</i> telescopes.	teachers
	<i>Introduction to SPIRIT</i> quick guide	This guide helps students take their first images with the <i>SPIRIT</i> telescopes.	students
	<i>SPIRIT observation log</i> worksheet	This worksheet guides students to select four deep sky objects to image using the <i>SPIRIT</i> telescopes. They describe, classify and publish a report on their selected objects.	students

### Purpose

To **Explore** the characteristics of astronomical objects by using the *SPIRIT* telescopes to image deep sky objects.

### Outcomes

Students:

- use the *SPIRIT* telescopes to image deep sky objects, including open and globular star clusters, galaxies and nebulae; and
- research objects they have imaged and publish a report describing them.

### Activity summary

ACTIVITY	POSSIBLE STRATEGY
<b>In class</b>  Teacher poses questions, such as: <ul style="list-style-type: none"> <li>What different kinds of objects can we see with the naked eye in the night sky?</li> <li>What other kinds of objects might we be able to see if we had access to a powerful telescope?</li> </ul>	whole class, teacher-directed questions  whiteboard summary of answers
Teacher provides information about the <i>SPIRIT</i> telescope initiative through presentation of the <i>SPIRIT</i> web site: <a href="http://spice.wa.edu.au/spirit/">http://spice.wa.edu.au/spirit/</a>  Teacher details the process for using <i>SPIRIT</i> telescopes (see <b>Telescope access</b> on the <i>SPIRIT</i> web site).	teacher-led, whole class  small groups
Students spend time exploring the <i>SPIRIT</i> web site. Particular attention should be given to content in <b>Guides and documents</b> , including <i>SPIRIT exposure guide</i> and <i>Taking your first image with SPIRIT</i> .	small groups
Teacher demonstrates logging onto <i>SPIRIT I</i> or <i>SPIRIT II</i> and provides an overview of the imaging interface. Particular attention is given to the process of taking an image, and location of student images and files.  NOTE: The demonstration can be completed in class time, however the telescope is unable to image astronomical objects during daylight hours.	teacher demonstration

ACTIVITY	POSSIBLE STRATEGY
Teacher distributes the guide, <i>Introduction to SPIRIT</i> , and worksheet, <i>SPIRIT observation log</i> , divides the class into small groups, issues user names and passwords and allocates a 30-minute evening time slot for each group to access the telescope.	small groups
Teacher provides a target list of deep sky objects from which students select four objects to image during their allocated 30-minute time slot.	
Students use Stellarium to plan how they will capture their images from a home computer.	
<b>On observation night</b>  Using instructions in the guide, <i>Introduction to SPIRIT</i> , students log onto a <i>SPIRIT</i> telescope and image four objects selected earlier from the target list. Record details of each image in observation log.  Students must capture their four images in the 30-minutes allocated to their group and must log off to allow next group to access the telescope.	small groups
<b>In class</b>  Students download their images and research objects they have imaged. They write a paragraph about each object, then combine their image and description into a report, as described in the worksheet.	small groups and individual work
Teacher arranges a class exhibition of reports. Students select the best images to upload to the <i>SPIRIT</i> telescope gallery.	students vote on the best images
Using students' image gallery, teacher poses a series of questions to draw together knowledge students have discovered during the activity, such as:  <ul style="list-style-type: none"> <li>• What different types of objects did you image with the telescope?</li> <li>• What similarities and differences can you see in images of open and globular star clusters?</li> <li>• What similarities and differences can you see in images of nebulae?</li> <li>• What similarities and differences can you see in images of galaxies?</li> <li>• Can you suggest how galaxies could be classified, according to their shape?</li> <li>• What did you learn about the way astronomers work, from your use of the <i>SPIRIT</i> telescopes?</li> <li>• What did you enjoy/learn from using the <i>SPIRIT</i> telescopes?</li> <li>• What other activities would you like to do using the <i>SPIRIT</i> telescopes?</li> </ul>	small group discussion or whole class sharing of ideas, whiteboard summary.

## Information for teachers

It is strongly advised that teachers wishing to undertake this activity contact the *SPIRIT* program manager at SPICE to seek assistance in planning the activity and allocating time for telescope booking.

This activity requires students, individually or in small groups, to have access to a computer in class and at home. It is designed in three parts:

1. In class, students familiarise themselves with the *SPIRIT* telescope interface.
2. At home, students log onto a *SPIRIT* telescope and image four objects selected earlier from target list provided by teacher.
3. In class, students download their images, research objects they imaged and write a report on each object.

The worksheet, *SPIRIT observation log*, guides students to select objects and command the telescope to image them remotely from their home computer, in real time, during an allocated 30-minute period. The worksheet provides a structure to help students compile reports for publication in a classroom image gallery.

The best images from each class may be submitted to the *SPIRIT* telescope image gallery for entry in an 'Image of the month' competition. Images will be published on the *SPIRIT* website.

The background sheet, *Deep sky objects*, contains images and information about four categories of target objects: galaxies, nebulae, globular star clusters and open star clusters.

## The *SPIRIT* telescopes

*SPIRIT* is an acronym for SPICE-physics-ICRAR remote Internet telescope. The *SPIRIT* telescopes are jointly funded by SPICE, the School of Physics at The University of Western Australia and the International Centre for Radio Astronomy Research (ICRAR).

*SPIRIT* is optimised for imaging deep sky objects, ie objects other than individual stars and parts of the Solar System. The telescopes are fitted with a monochrome CCD camera for maximum sensitivity to light. The telescopes have a range of filters, including:

- narrow band **blue, visual and red (B, V, and R)** filters used for photometric studies of stars, such as measuring their temperatures and luminosity;
- **red, green and blue** photographic filters used to create colour images;
- a **clear filter** for all other imaging. This is the recommended filter when using the telescope for the first time.

*SPIRIT* can be used to image the brighter planets, such as Jupiter and Saturn, using exposures of less than one second. However images tend to appear small and unremarkable. *SPIRIT* is not suitable for viewing the Sun or Moon.

The telescope interface includes drop-down menus to explain terminology, abbreviations and function of various telescope parts.

Detailed technical descriptions of both *SPIRIT* telescopes can be found at:  
<http://spice.wa.edu.au/spirit-technical-description/>

## Targets

Target lists are arranged in four categories:

CATEGORY	TYPE OF DEEP SKY OBJECT
1	galaxy
2	nebula
3	globular star cluster
4	open star cluster

Students select one object from each category to image. They are not informed what these categories are at the beginning of the activity.

The guide, *Introduction to SPIRIT*, steps students through use of *SPIRIT* to image a deep sky object. Students should follow these instructions during night-time use of the telescope.

To help students successfully use *SPIRIT*, monthly target lists of suitable deep sky objects are provided.

Lists identify objects visible and well positioned at 9pm on the 15<sup>th</sup> of each month. Lists are further divided into targets west of the meridian and targets east of the meridian<sup>1</sup> to allow for the westward movement of objects across the sky during the night, and over the course of the chosen month.

Targets west of the meridian are 'setting'. Objects in this group are best imaged early in the month, before the 15<sup>th</sup>. In the second half of the month they should be imaged in the early evening, before 9pm. They may have disappeared altogether (set) by late evening towards the end of the month.

Targets east of the meridian are 'rising'. Objects in this list are best imaged in the second half of the month (after the 15<sup>th</sup>). In the first half of the month they should be imaged late in the evening. At the beginning of the month they may not rise high enough for imaging early in the evening.

Bright nebulae are comparatively rare, so lists for these have not been divided into east and west targets.

Stellarium can be used to verify the sky position of any selected target for the date and time of a *SPIRIT* booking. Students should choose objects best positioned (highest in the sky) to avoid the effects of atmospheric and light pollution.

Some targets are better than others. For example, the most famous of all globular clusters are NGC 5139 and NGC 104. These should always be included if they are up at the time of imaging. A 'top twenty' list of deep sky objects is provided in Appendix 1.

Target lists include bright objects where possible. Most can be imaged with exposures of 60 s or less. Exposures of bright open and globular clusters are typically around 30 s. Galaxies and nebulae will benefit from exposures of 60 s or more.

Open clusters, globular clusters and nebulae tend to be concentrated near the galactic plane, as these objects are located in our own galaxy, the Milky Way. On the other hand, galaxies are easiest to find when looking perpendicular to the galactic plane as the view out of our galaxy into intergalactic space is less 'cluttered'. This partially explains why some months are better than others for certain object types.

Target lists are not exhaustive. Many thousands of galaxies, clusters and nebulae can be imaged by *SPIRIT*. Interested students should be encouraged to investigate other potential targets using resources such as Stellarium and the Internet.

## Technical requirements

A login and password to access *SPIRIT* can be requested using an on-line form located on the *SPIRIT* web site. However, teachers unfamiliar with the *SPIRIT* initiative are invited to make contact with SPICE before requesting access.

It is strongly recommended that teachers have experience in using the *SPIRIT* telescopes before attempting the activity with students.

SPICE offer a number of teacher and student workshops to cater for a wide range of activities using *SPIRIT*. More information can be found at:  
<http://spice.wa.edu.au/spirit/spirit-pd/>

The guide, background sheet and worksheet require Adobe Reader, which is a free download from [www.adobe.com](http://www.adobe.com). The worksheet is also provided in Microsoft Word format.

<sup>1</sup> The meridian is an imaginary line that joins due north with due south and passes directly overhead. It effectively splits the sky into two (east and west of the meridian).

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## Associated SPICE resources

*Evolution of the Universe 2: The SPIRIT telescopes* may be used in conjunction with related SPICE resources to address the broader topic of how astronomers study the visible Universe and its origins.

DESCRIPTION	LEARNING PURPOSE
<i>Evolution of the Universe (overview)</i>  This learning pathway shows how a number of SPICE resources can be combined to teach the topic of the origin and evolution of the Universe.	
<i>Evolution of the Universe 1: Galaxies</i>  Students are introduced to astronomy through use of Stellarium planetarium software to classify galaxies visible in the night sky.	Engage
<i>Evolution of the Universe 2: The SPIRIT telescopes</i>  Students explore the night sky using a remotely-operated telescope. They image deep sky objects in real time; research these objects; and publish their images.	Explore
<i>Evolution of the Universe 3: History of the Universe</i>  The Big Bang theory is used to explain the origin and subsequent development of the Universe.	Explain
<i>Evolution of the Universe 4: Stars</i>  Students use filters on the SPIRIT telescopes to capture images of a star cluster and compile a full-colour image. They use this image to discover why stars differ in colour, and relate star colours to stages in stellar life cycles.	Elaborate

## Appendix 1: Deep sky objects 'Top 20 list' for the *SPIRIT* telescope

Objects in this list are excellent targets for imaging with *SPIRIT*. They are ordered by RA.

OBJECT	RA (2000.0)	Dec (2000.0)	TYPE	COMMON NAME
NGC 104	00h 24m 05s	-72° 04' 49"	globular cluster	47 Tucanae
NGC 253	00h 47m 33s	-25° 17' 15"	intermediate spiral galaxy	Sculptor Galaxy
NGC 300	00h 54m 53s	-37° 41' 03"	spiral galaxy	
NGC 1365	03h 33m 37s	-36° 08' 27"	barred spiral galaxy	Great Barred Galaxy
M 42	05h 35m 17s	-05° 23' 25"	nebula	Orion Nebula
NGC 2070	05h 38m 38s	-69° 05' 39"	nebula	Tarantula Nebula
NGC 3372	10h 43m 50s	-59° 52' 00"	nebula	Carina Nebula
NGC 4038	12h 01m 53s	-18° 51' 52"	interacting galaxy pair	Antennae Galaxies
M 104	12h 39m 59s	-11° 37' 21"	unbarred spiral galaxy	Sombrero Galaxy
NGC 4755	12h 53m 37s	-60° 21' 22"	open cluster	Jewel Box
NGC 4945	13h 05m 26s	-49° 27' 46"	spiral galaxy	
NGC 5128	13h 25m 29s	-43° 00' 58"	lenticular or elliptical galaxy	Centaurus A
NGC 5139	13h 26m 47s	-47° 28' 51"	globular cluster	Omega Centauri
M 83	13h 37m 00s	-29° 52' 02"	barred spiral galaxy	Southern Pinwheel Galaxy
M 20	18h 02m 28s	-22° 59' 19"	open cluster and nebula	Trifid Nebula
M 8	18h 04m 21s	-24° 18' 16"	nebula	Lagoon Nebula
M 16	18h 18m 55s	-13° 50' 41"	open cluster and nebula	Eagle Nebula
M 17	18h 20m 48s	-16° 11' 00"	open cluster and nebula	Omega Nebula
M 27	19h 59m 36s	+22° 43' 18"	planetary nebula	Dumbbell Nebula
NGC 7293	22h 29m 38s	-20° 50' 11"	planetary nebula	Helix Nebula

## Appendix 2: Target list of suitable deep sky objects

Lists of deep sky objects that are suitable targets for students to image with the *SPIRiT* telescopes are available. Target lists show selected deep sky objects that are best viewed between 8:00 pm and 11:00 pm, at higher altitudes. In the early part of a month (before 15<sup>th</sup>) best results will be obtained with targets west of the meridian. In the latter part of a month (after 15<sup>th</sup>) targets east of the meridian should be selected.

January and February target lists are shown as an example. Lists for all months can be downloaded from the SPICE website at <http://spice.wa.edu.au/spice-initiatives/spirit/documents/>.

### JANUARY and FEBRUARY deep sky objects

OBJECT	JANUARY			FEBRUARY		
	RA (2000)	DECL (2000)		RA (2000)	DECL (2000)	
<b>Category 1 (west of meridian)</b>						
NGC 1532	04h 12m 04s	-32° 52' 23"	NGC 1792	05h 05m 14s	-37° 58' 47"	
NGC 1566	04h 20m 00s	-54° 56' 18"	NGC 1532	04h 12m 04s	-32° 52' 23"	
NGC 1546	04h 14m 37s	-56° 03' 37"	NGC 1672	04h 45m 43s	-59° 14' 52"	
NGC 1313	03h 18m 16s	-66° 29' 43"	NGC 1313	03h 18m 15s	-66° 29' 51"	
NGC 1365	03h 33m 37s	-36° 08' 27"	NGC 1566	04h 20m 01s	-54° 56' 14"	
NGC 1097	02h 46m 19s	-30° 16' 32"	NGC 1546	04h 14m 37s	-56° 03' 37"	
NGC 1232	03h 09m 45s	-20° 34' 45"	NGC 1433	03h 42m 01s	-47° 13' 19"	
NGC 1068	02h 42m 40s	-00° 00' 48"	NGC 1792	05h 05m 14s	-37° 58' 47"	
NGC 300	00h 54m 54s	-37° 40' 57"	NGC 2217	06h 21m 40s	-27° 14' 03"	
<b>Category 1 (east of meridian)</b>						
NGC 1637	04h 41m 28s	-02° 51' 28"	NGC 2442	07h 36m 24s	-69° 31' 50"	
NGC 1808	05h 07m 42s	-37° 30' 48"	NGC 2280	06h 44m 49s	-27° 38' 20"	
NGC 1792	05h 05m 14s	-37° 58' 47"	NGC 2292	06h 47m 39s	-26° 44' 47"	
NGC 1617	04h 31m 40s	-54° 36' 07"	NGC 2325	07h 02m 40s	-28° 41' 52"	
NGC 1672	04h 45m 43s	-59° 14' 52"	NGC 3059	09h 50m 08s	-73° 55' 17"	
NGC 1964	05h 33m 22s	-21° 56' 43"	NGC 2559	08h 17m 06s	-27° 27' 25"	
NGC 2196	06h 12m 10s	-21° 48' 22"	NGC 2566	08h 18m 46s	-25° 30' 02"	
NGC 2217	06h 21m 40s	-27° 14' 03"	NGC 2613	08h 33m 23s	-22° 58' 22"	
NGC 2442	07h 36m 20s	-69° 31' 29"				
<b>Category 2</b>						
M 42	05h 35m 17s	-05° 23' 25"	M 42	05h 35m 17s	-05° 23' 25"	
NGC 2070	05h 38m 38s	-69° 05' 39"	NGC 2070	05h 38m 38s	-69° 05' 39"	
NGC 2024	05h 41m 42s	-01° 50' 43"	NGC 2024	05h 41m 42s	-01° 50' 43"	
NGC 2237	06h 30m 55s	+05° 02' 52"	NGC 2237	06h 30m 55s	+05° 02' 52"	
<b>Category 3 (west of meridian)</b>						
NGC 1261	03h 12m 15s	-55° 12' 59"	NGC 1851	05h 14m 06s	-40° 02' 48"	
NGC 362	01h 03m 14s	-70° 50' 52"	NGC 288	00h 52m 46s	-26° 35' 10"	
NGC 104	00h 24m 06s	-72° 05' 00"	NGC 1261	03h 12m 15s	-55° 12' 59"	
NGC 288	00h 52m 46s	-26° 35' 10"	NGC 362	01h 03m 14s	-70° 50' 52"	
			NGC 104	00h 24m 05s	-72° 04' 49"	
<b>Category 3 (east of meridian)</b>						
NGC 1851	05h 14m 06s	-40° 02' 48"	NGC 2298	06h 48m 59s	-36° 00' 17"	
NGC 2298	06h 48m 59s	-36° 00' 17"	NGC 2808	09h 12m 03s	-64° 51' 45"	
NGC 2210	06h 11m 32s	-69° 07' 15"	NGC 3201	10h 17m 36s	-46° 25' 00"	
NGC 2808	09h 12m 03s	-64° 51' 45"				
<b>Category 4 (west of meridian)</b>						
NGC 371	01h 03m 30s	-72° 03' 25"	M 35	06h 09m 00s	+24° 21' 00"	
M 45	03h 46m 06s	+24° 08' 49"	NGC 1963	05h 32m 12s	-36° 23' 00"	
NGC 346	00h 59m 05s	-72° 10' 38"	NGC 2042	05h 36m 10s	-68° 55' 25"	
			NGC 2180	06h 09m 36s	+04° 42' 44"	
			NGC 2202	06h 16m 51s	+05° 59' 48"	
<b>Category 4 (east of meridian)</b>						
M 41	06h 46m 00s	-20° 45' 15"	M 50	07h 02m 48s	-08° 23' 00"	
M 93	07h 44m 29s	-23° 51' 11"	M 93	07h 44m 29s	-23° 51' 11"	
M 47	07h 36m 35s	-14° 28' 47"	M 46	07h 41m 47s	-14° 48' 36"	
M 46	07h 41m 47s	-14° 48' 36"	M 47	07h 36m 35s	-14° 28' 47"	
M 50	07h 02m 48s	-08° 23' 00"	M 48	08h 13m 43s	-05° 45' 02"	
NGC 2348	07h 03m 03s	-67° 23' 38"	NGC 2516	07h 58m 07s	-60° 45' 12"	
			NGC 2547	08h 10m 11s	-49° 14' 00"	

Early in a month, targets west of the meridian will be best.

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Late in a month, targets east of the meridian will be best.

### Appendix 3: Glossary of terms relevant to the *SPIRIT* telescope

azimuth and altitude	<p>Azimuth/altitude (Az/Alt) is a method of describing the position of stars as viewed from a particular location at a particular time.</p> <p>Azimuth (Az) corresponds to the compass bearing of the direction the telescope is pointing. When the telescope is pointing at Az 90° it is facing due east; at Az 180° it is pointing south, and so on.</p> <p>Altitude (Alt) is a measure of how 'high' the telescope is pointing above the horizon. It ranges from 0 to 90 degrees. An object with altitude of 0° is on the horizon, while an object at 90° altitude is directly overhead.</p> <p>A disadvantage with using Az/Alt is that Earth's rotation causes an object's azimuth and altitude coordinates to change constantly.</p>
Coordinated Universal Time (UTC)	<p>Sometimes called Universal Time, UTC is a modern version of Greenwich Mean Time (GMT), which divides Earth into 24 time zones, starting from 'zero hour' at Greenwich in England.</p> <p>Astronomers use Universal Time to avoid confusion that might arise from working in different time zones.</p> <p>The <i>SPIRIT</i> telescope is located in Perth, which is 8 hours east of Greenwich, so we say Perth is UTC +8.</p>
Local Sidereal Time (LST)	<p>Relative to the stars, Earth rotates on its axis once every 23 hours 56 minutes and 4 seconds. Relative to the Sun, it rotates once every 24 hours. Consequently, stars appear to rise approximately four minutes earlier each night.</p> <p>Astronomers use local sidereal time to determine the position of stars in the sky.</p>
meridian	<p>The meridian is an imaginary line across the sky from north to south that passes directly overhead.</p>
right ascension and declination	<p>Stars can be plotted on a coordinate system, similar to the longitude and latitude system used on Earth, if they are imagined as fixed objects on a 'celestial sphere'. Coordinates in the night sky are called right ascension and declination (RA/Dec).</p> <p>Right ascension (RA) is a measure of how far an object is east or west of the meridian. The night sky is divided into 24 hours of right ascension that increase as we travel east across the sky. Right ascension is similar to longitude on Earth.</p> <p>Declination (Dec) is a measure of how far an object is north or south of the celestial equator. Starting with zero degrees at the celestial equator, objects extend to 90° north or 90° south. Declination is similar to latitude on Earth.</p> <p>An advantage with using RA/Dec to describe star positions is that coordinates remain the same, regardless of Earth's rotation or the observer's location.</p>

## Appendix 4: Glossary of astronomical terms

astronomical catalogues	<p>Most astronomical objects have been catalogued and are known by their catalogue reference number. However some, such as the Andromeda galaxy, are also known by a traditional name. Common astronomical catalogues include:</p> <p><b>Messier catalogue</b></p> <p>In 1771 Charles Messier made one of the earliest attempts to name and catalogue astronomical objects. Messier was a comet hunter who simply grouped together objects that resembled, but were not, comets. His catalogue eventually grew to 110 objects that include open clusters, globular clusters, nebulae and galaxies.</p> <p>In the Messier catalogue, the Andromeda Galaxy is known as M 31; the Crab nebula is M 1 and the Sombrero galaxy is M 104.</p> <p><b>NGC catalogue</b></p> <p>The New General Catalogue (NGC), published in 1888, was an attempt to collate many lists in existence at that time into one master list. It catalogues almost 8000 objects, including galaxies, nebulae and star clusters.</p> <p>NGC 1 is a spiral galaxy in the constellation Pegasus; NGC 188 is an open cluster in the constellation Cassiopeia; and NGC 2022 is a planetary nebula in Orion.</p> <p><b>PGC catalogue</b></p> <p>The Catalogue of Principal Galaxies (PGC) is an astronomical catalogue published in 1989 that lists about 73 000 galaxies.</p> <p>Many astronomical objects are known by more than one catalogue reference number.</p>
galaxies	<p>A galaxy is a massive conglomeration of stars, stellar remnants, interstellar gases, dust and dark matter held together by gravity.</p> <p>Galaxies range in size from dwarfs with as few as ten million stars to giants with hundreds of trillions of stars orbiting the galaxy's centre of mass.</p> <p>Galaxies are classified according to their apparent shape: elliptical; spiral; or irregular. There are probably more than 170 billion (<math>1.7 \times 10^{11}</math>) galaxies in the observable Universe.</p>
globular star cluster	<p>A globular star cluster is a spherical collection of stars that orbits the centre of a galaxy. The cluster is held together by gravity, which determines its spherical shape and relatively high stellar density.</p> <p>The Milky Way Galaxy contains about 150 known globular clusters, with perhaps 10 to 20 more undiscovered.</p>
nebula	<p>A nebula is an interstellar cloud of dust, hydrogen, helium and other ionised gases.</p> <p>Large nebulae are frequently places where star clusters are formed. In these regions gas, dust and other materials 'clump' together to form larger masses, which attract further matter, and eventually become big enough to form stars. Any remaining materials are believed to form planets and planetary system objects.</p>
open star cluster	<p>An open star cluster is a group of up to a few thousand stars that were formed, from the same giant interstellar cloud of gas, at roughly the same time. The stars are loosely bound to each other by gravitational attraction. Open clusters can be disrupted by close encounters with other clusters and gas clouds, which can result in the loss or gain of stars. Open clusters generally survive for a few hundred million years.</p>