

Mapping the Cosmos

A Card Game (2-4 players)

Introduction

Astronomers survey the sky for many different reasons. This could be to do science with large samples of objects or to look for rare things to study with more observations. The Sloan Digital Sky Survey (SDSS) takes spectra of stars, galaxies and massive black holes known as quasars. A spectrum is the light of an astronomical object split up into all its different colors. SDSS observes hundreds of objects at the same time. This is done by feeding the light from a telescope to a special instrument where hundreds of tiny robots that position fiberoptic cables. They position these cables to match the position of a star, galaxy or quasar. Each of these cables leads to an instrument known as a spectrograph for measuring the spectrum of that object.

Different astronomers study different types of objects. They often collaborate together on projects where lots of different astronomers with different interests work together so they can all get their observations done to pursue their own science goals. But surveys also have a legacy value. If you make lots of observations of the sky public then other astronomers can use those observations for their own science goals and give you the credit for taking the observations.

Astronomy isn't always the easiest science. You have to contend with poor weather or instrument problems. You also have to deal with moonlight. When the moon is in the sky and close to being a full moon it floods the sky with lots of blue light. This is called bright time when it is harder to observe and when it is especially hard to observe blue targets. Conversely when the moon is not in the sky it is dark time, when observing is easier.

Sometimes astronomers can get lucky and have the chance to observe exploding stars known as supernovae or explosions on white dwarfs known as novae. Very occasionally they might get the chance to look for the light from a gravitational wave event where colliding black holes have been detected by a gravitational wave observatory. Collectively these chance observations are called Targets of Opportunity (ToO).

The game isn't exactly like how astronomers in the Sloan Digital Sky Survey operate. It has dedicated telescopes so can observe all night, can observe different types of target at the same time & its observatory directors aren't decks of cards. But it does show how astronomers need to balance the needs of lots of scientists when doing a survey of the sky.

Setup

Firstly, remove the legacy survey card from the science goals deck and place it face up. Shuffle the rest of the cards in the science goals deck.

There are two ways to set up, quick play if you want to start quickly and normal play.

Quick play: for each player put one randomly selected 1 hour card, 2 two hour cards and one each of 3,4,5 and 6 hour cards in a deck and shuffle. Remove the extra observatory cards (those marked with an *) and put all the other event cards in a deck and shuffle.

Normal play: Start by building the time and event decks. Split the time deck into six piles of 1, 2, 3, 4, 5 and 6 hour cards, shuffle each. Split the event deck into weather, observatory and ToO cards, shuffle each. Remove all the extra observatory cards (those marked with an *) and don't use them in the game.

Time deck: add two one hour time cards per player and two two hour time cards per player to the time deck, shuffle the deck.

Event deck: for each player add one randomly selected weather card, two randomly selected observatory card and three randomly selected ToO cards. Shuffle the deck.

Before the start of turns 2-6 you will add more cards to the decks.

Before turn 2: add two two hour time card per player to the time deck and add one randomly selected weather card per player to the event deck, shuffle both decks.

Before turn 3: add two three hour time card per player to the time deck and add one randomly selected weather card per player to the event deck, shuffle both decks.

Before turn 4: add two four hour time card per player to the time deck and add one randomly selected weather card per player to the event deck, shuffle both decks.

Before turn 5: add two five hour time card per player to the time deck and add one randomly selected weather card per player to the event deck, shuffle both decks.

Before turn 6: add two six hour time card per player to the time deck and add one randomly selected weather card per player to the event deck, shuffle both decks.

Gameplay

In this game each player takes the role of an astronomer carrying out a survey of objects in the sky. At the start of the game, you will each draw one science goal card. This will say what your science goal is. Keep this card until the end of the game.

Each turn (which represents a month) each player will be given observing time on three nights by the observatory director (three cards from the time deck). Place these three cards in a row in-front of you. Next, each player will also draw one event card. This could be bad weather, an interesting Target of Opportunity (ToO) or something happening at the observatory.

Each player can then spend the time from each night to observe one type of object. There are four types of objects in the game: white dwarfs, nearby quasars, distant quasars and red giants. Each have slightly different observational properties. A player may only use the time on **one time card for one type of object** with the exception of Targets of Opportunity.

Any player who draws a Targets of Opportunity (ToO) card can observe it by using part of the time on one night. So, for example a player with a ToO that needs one hour to observe and a two hour time card can spend one hour from this card to observe the ToO and can use the rest of the time on that card to observe one other type of object. At the end of each turn keep any target of opportunity cards you observed, discard any unobserved ToO cards.

At the end of every turn return all of the used time cards to the time deck. Discard all used event cards except observed Target of Opportunity cards. Shuffle both decks.

The game lasts for 6 turns, with each turn representing a month. In quick play each month is equal. In normal play the game starts in the summer when the nights are short but the weather is good. As the turns progress the nights get longer but the weather gets worse.

At the end of the game the legacy survey prize will be awarded to the player with the best legacy survey. You will need to observe the widest range of objects you can to win this prize.

Using Observing Time

White Dwarfs

blue and faint

500 objects per hour of dark time
200 objects per hour of bright time
Score 1 point per 400 white dwarfs

Nearby Quasars

blue and bright

1000 objects per hour of dark time
400 objects per hour of bright time
Score 1 point per 800 nearby quasars

Distant Quasars

red and faint

500 objects per hour of dark time
400 objects per hour of bright time
Score 1 point per 500 distant quasars

Red Giants

Red and bright

1000 objects per hour of dark time
800 objects per hour of bright time
Score 1 point per 1000 red giants

Legacy Survey Prize

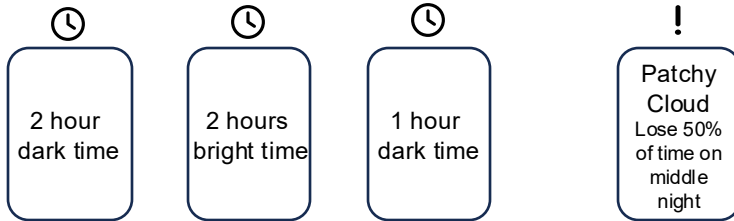
Awarded to the player who has the widest range of objects observed after 6 turns. Look at the four types of objects. The lowest number of the four types of object is your legacy survey score. The player with the highest legacy survey score wins the legacy survey prize and the points it brings.

Example: Two players have collected the following number of objects. The lowest number of the 4 types of object player 1 has is 4000, that is his legacy survey score. The lowest number of objects player 2 has is 5000, that is her legacy survey score. In this situation player 2 wins the legacy survey bonus card and the 20 points it brings.

	White dwarfs	Nearby Quasars	Distant Quasars	Red Giants
Player 1	<u>4000</u>	8000	6000	10000
Player 2	6000	7000	<u>5000</u>	7000

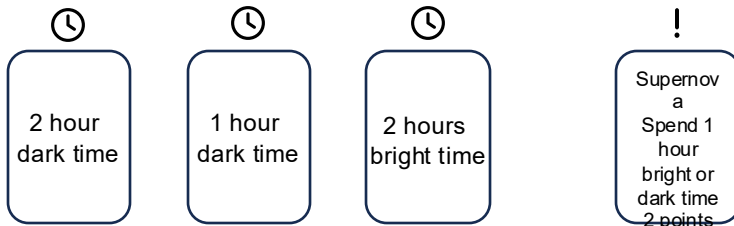
An Example Turn

Player 1 draws the following time and event cards



Player 1 uses his 2 hours on the first night to observe white dwarfs. He has lost half of his time on the middle night to cloud so uses the remaining hour to observe red giants and then also uses the 1 hour on the last night to observe white dwarfs. He notes down 1500 white dwarfs and 800 red giants in the row for this turn on his scorecard.

Player 2 draws the following time and event cards



Player 2 uses her 2 hours on the first night to observe nearby quasars. She use the 1 hour on the middle night to observe white dwarfs. Finally she uses one hour of the time on the last night to observe her Target of Opportunity (ToO) supernova and the remaining one hour on the last night of time to observe distant quasars. As player 2 observed her ToO card she keeps it until the end of the game. She notes down 500 white dwarfs, 2000 nearby quasars and 400 distant quasars in the row for this turn on her scorecard.

Variants to Try

If you've played the game a few times then why not try one of these variants to make things a bit different.

- **Extra Observatory Cards:** Use the extra observatory cards (those marked with an *) in the game
- **Trading Time:** Each turn, once all players have drawn all time and event cards, players can trade time by bartering with other players. If a player trades time on a night affected by a weather card, the effect of that weather card is applied to the time before it is traded
- **More Science Goals:** Allow players who have completed their science goal to draw a new science goal. If a player draws a new science goal and then doesn't complete it then subtract the points on the card for that science goal from that player's total at the end.
- **Target of Opportunity Priority:** ToOs are very important so you should be able to take control of the telescope to observe one. In this variant if you draw a ToO card, you may use it to take the exact amount of time listed on the card from another player. You use that amount of time from the other player to observe your ToO and they cannot use that time. All players will need to draw time and event cards for a turn/month at the same time to make this work.
- **The full year:** Play a longer version of the game in normal play by adding an extra six months. When doing this double the number of objects needed to complete each science goal and double the points for all science goals. The first six turns operate the same as the normal play rules with one exception, so not discard your event cards (with the exception of ToO cards) and shuffle them back in to the deck. At the start of turn 7, two new ToO cards per player are added to the deck. After turn 7 remove cards from the time and event deck in the...

Variants to Try (cont.)

reverse order you added them in the first 6 months. So, at the start of turn 8 remove the 6 hour cards from the time deck and one weather card per player from the event deck. Then remove all the 5 hour cards and one weather card per player at the start of turn 9, etc. Use a second scorecard for the second six months. All observations across the twelve months towards science goalsß.

Credits

Game: Sloan Digital Sky Survey/Niall Deacon

Image credits: Sloan Digital Sky Survey

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Science Goals – Stephan's Quintet, Box image – Abell 2151

Icon credits: Font Awesome by Dave Gandy - fontawesome.io

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Teacher Notes

This game presents a very simplified version of some of the trade-offs astronomers need to make when conducting surveys.

Some things your students may learn playing this game:

- Poor weather can affect astronomical observations
- Sometimes astronomical instruments have problems that may affect observations (the game exaggerates how often and severe these are).
- Much of science is done by large groups of scientists with different interests who work together
- Moonlight can affect astronomical observations, particularly when looking in blue light
- Luck can also be a factor
- Astronomers need to take lots of things into account when planning efficient observations

Some notes on specific cards: the red monster was a nickname given to an instrument problem that occasionally would affect the redder part of the spectrum. It made the spectra less accurate but didn't stop the observation of red objects. A bear did once get into the kitchen at the Apache Point Observatory, nobody was harmed by the bear. Moths do sometimes get into our spectrographs as they are nice, warm places. Other observatories sometimes have surprise visitors like scorpions. Bonsai is the dog of one of the staff at Apache Point, he's very friendly to visitors.

Notes on types of objects:

- White dwarfs are the remnants of stars that have reached the end of their hydrogen burning lives and then evolved first to giant stars and then to planetary nebulae. In the planetary nebula phase the dying star throws off its outer layers, leaving only the remaining hot dense core. This hot dense core is the white dwarf. White dwarfs cool over time at a predictable rate so can be used as probes of the history of our galaxy.
- Red giants are old stars that have finished burning hydrogen in their cores but haven't yet reached the point of evolving in to white dwarfs. They are bright and the different lines in their spectra can be used to estimate the abundances of different elements.
- Nearby and distant quasars are both types of quasars. Gas and dust falling towards supermassive black holes at the heart of distant galaxies can form a disk of material orbiting the black hole. The huge gravitational pull of these black holes can lead to these disks rotating extremely fast and the material in them becoming very hot. These huge hot disks of material are extremely bright and can outshine all of the stars in the surrounding galaxy a thousand times over. Quasars' spectra are redshifted, the more distant they are the more they are redshifted. This moves some of their bright emission features from ultraviolet light, to visible light, or for the most distant quasars, to the infrared. This changes the colours of the quasars, making more distant quasars appear redder.

Teacher Notes (cont.)

Notes on observing time:

- Astronomers typically try to observe objects so that they get a good ratio of signal to noise. If the signal to noise ratio of an observation of an object is too low then noise could make measurements of the properties of that object too inaccurate to use. Normally the longer you observe for, the better your signal to noise ratio. But at some point once an object has been observed for long enough, the signal to noise ratio is high enough for the purposes the astronomer wants to use the observation for so it would be a waste of time to observe for longer.
- The fainter the object, the longer you would need to observe to get the required signal to noise ratio.
- The brightness of an astronomical object is a combination of the object's intrinsic brightness and how far away that object is.
- The game over-simplifies brightness into objects being either bright or faint
- The moon affects observations. When the moon is close to full and in the sky it emits a lot of blue light. This means that if you are trying to study objects where their properties in blue light is important, the observations will be made worse by the moon being in the sky. Hence astronomers prefer to observe faint, bluer objects in "dark time" when the moon is not in the sky as opposed to "bright time" when it is.

Here are several ways you could use this game in a wider lesson:

- Ask your students to research the different types of objects used in this game and why astronomers study their spectra.
- Ask the students about the usage of observing time. Why do they think fewer faint objects are observed per hour?
- Discuss with students how they would decide on how to allocate telescope resources. See if your students get something like the common model of writing proposals for observations and then a committee evaluating these proposals or if they have a different idea.
- Give students or groups of students one science goal card each and ask them to come up with arguments as to why this science goal is important. This will involve background research.

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1 hour
Dark Time

1 hour
Dark Time

1 hour
Dark Time

1 hour
Dark Time

1 hour
Dark Time

1 hour
Dark Time

1 hour
Bright Time

1 hour
Bright Time



2 hours
Dark Time

2 hours
Dark Time

2 hours
Dark Time

2 hours
Dark Time

2 hours
Dark Time

2 hours
Dark Time

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Dark Time

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Dark Time



2 hours
Bright Time

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3 hours
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Bright Time



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Bright time



5 hours
Dark Time

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Dark Time

5 hours
Bright Time

5 hours
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6 hours
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Bright Time

6 hours
Bright Time



5 hours
Dark Time

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Dark Time

5 hours
Dark Time

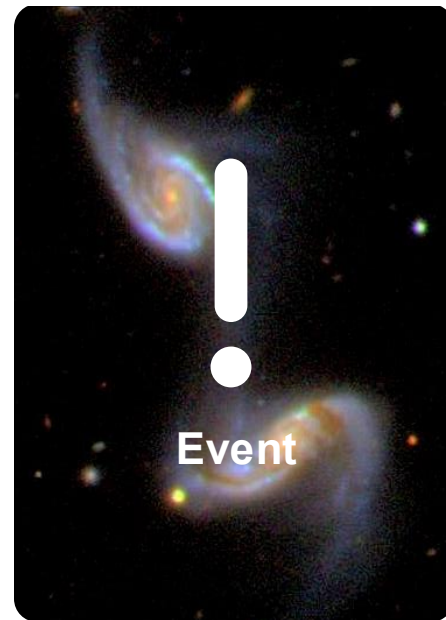
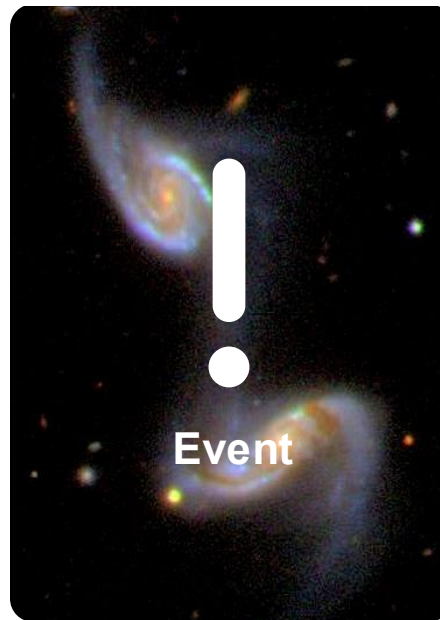
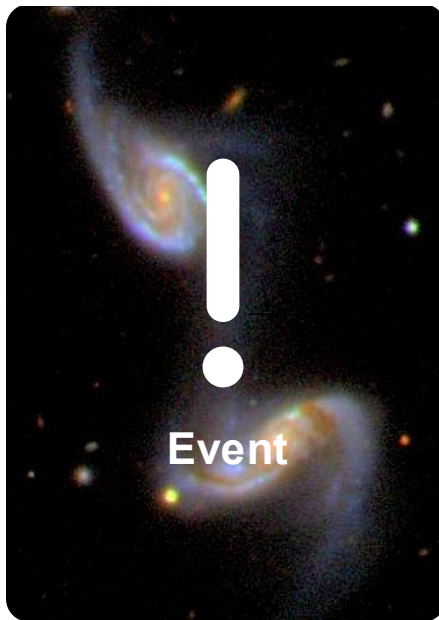
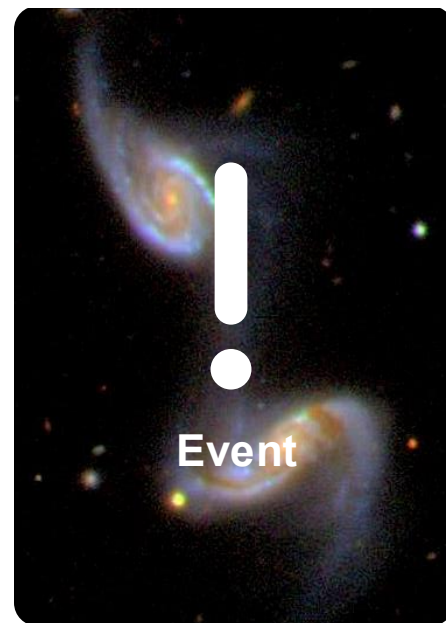
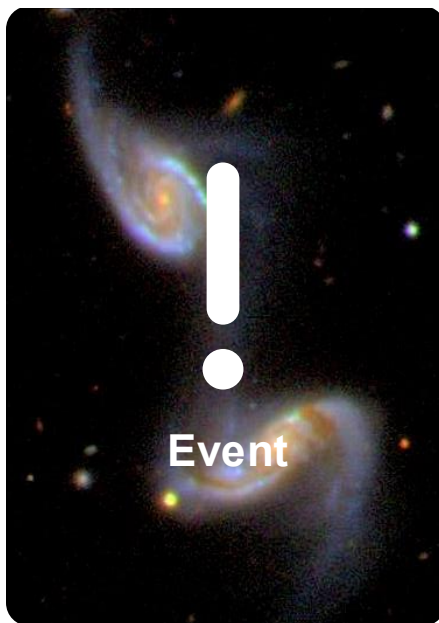
5 hours
Dark Time

6 hours
Dark Time

6 hours
Dark Time

6 hours
Dark Time

6 hours
Bright Time



ToO

Supernova

Spend 1 hour of bright or dark time to receive

2 points

If you observe this card keep it until the end of the game. Otherwise discard it

ToO

Supernova

Spend 1 hour of bright or dark time to receive

2 points

If you observe this card keep it until the end of the game. Otherwise discard it

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2 points

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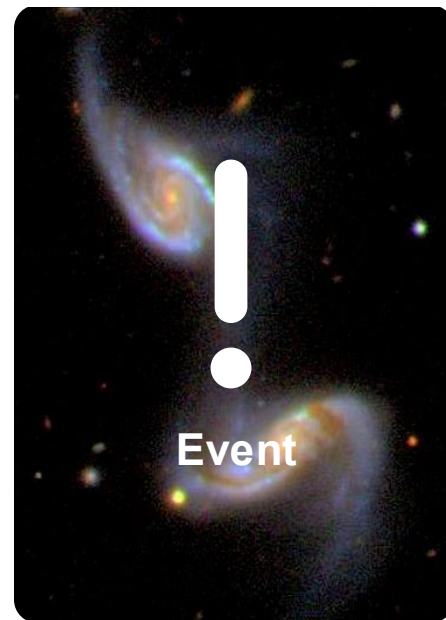
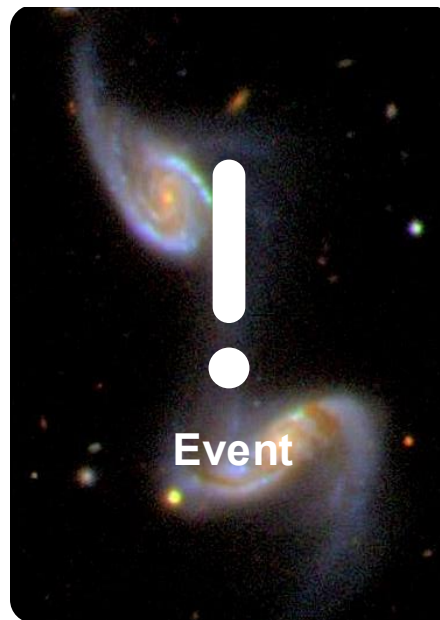
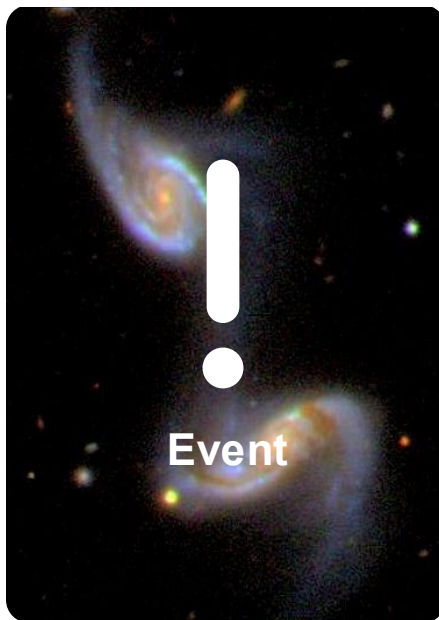
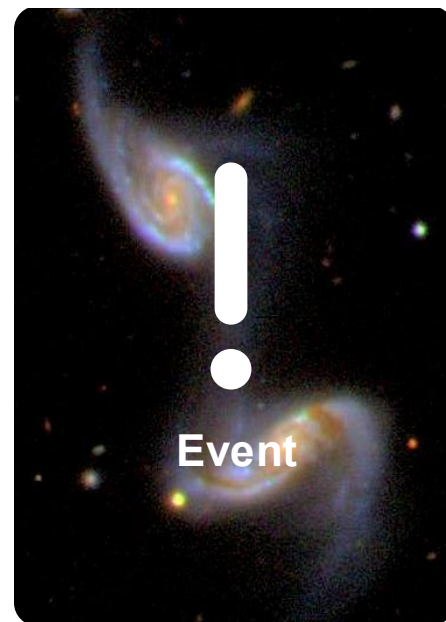
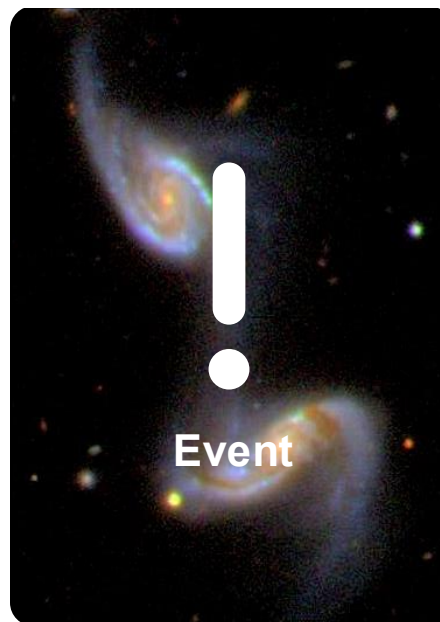
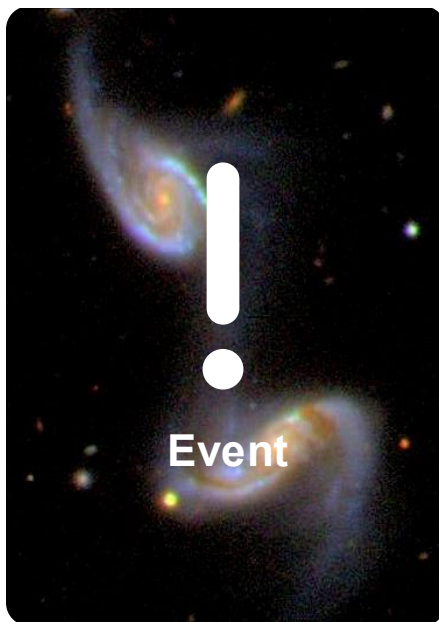
ToO

Supernova

Spend 1 hour of bright or dark time to receive

2 points

If you observe this card keep it until the end of the game. Otherwise discard it



ToO

Peculiar Supernova

Spend 2 hour of bright or
dark time to receive

4 points

If you observe this card
keep it until the end of the
game. Otherwise discard it

ToO

Peculiar Supernova

Spend 2 hour of bright or
dark time to receive

4 points

If you observe this card
keep it until the end of the
game. Otherwise discard it

ToO

Peculiar Supernova

Spend 2 hour of bright or
dark time to receive

4 points

If you observe this card
keep it until the end of the
game. Otherwise discard it

ToO

Peculiar Supernova

Spend 2 hour of bright or
dark time to receive

4 points

If you observe this card
keep it until the end of the
game. Otherwise discard it

ToO

Galactic Nova

Spend 2 hour of bright or
dark time to receive

5 points

If you observe this card
keep it until the end of the
game. Otherwise discard it

ToO

Galactic Nova

Spend 2 hour of bright or
dark time to receive

5 points

If you observe this card
keep it until the end of the
game. Otherwise discard it

ToO

Galactic Nova

Spend 2 hour of bright or
dark time to receive

5 points

If you observe this card
keep it until the end of the
game. Otherwise discard it

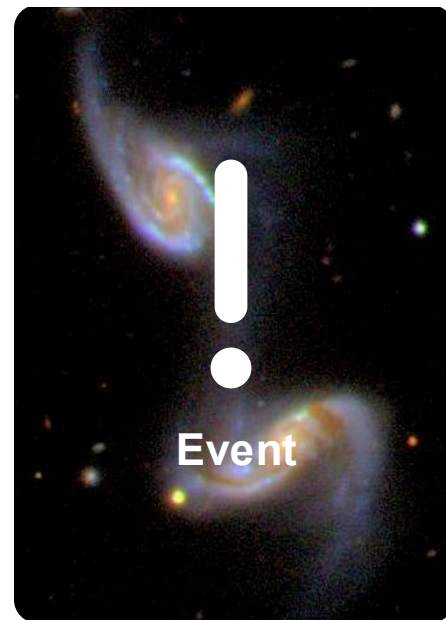
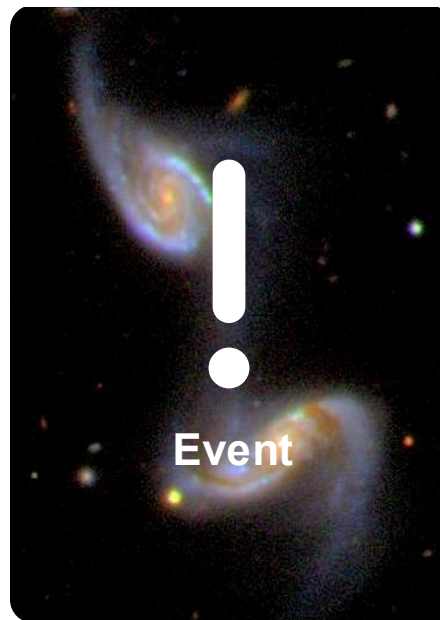
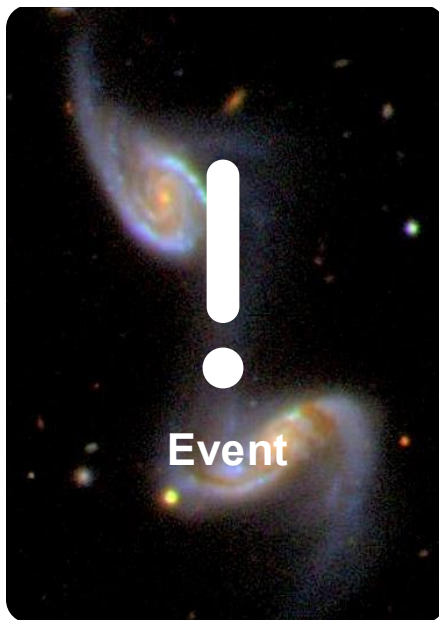
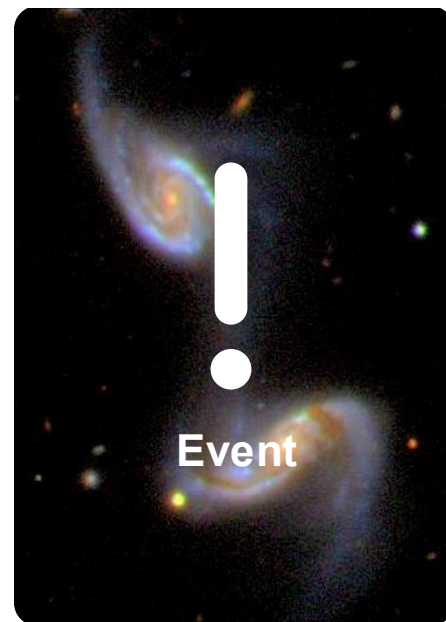
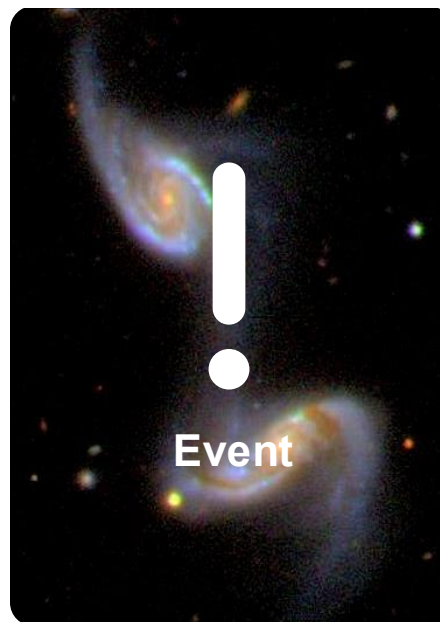
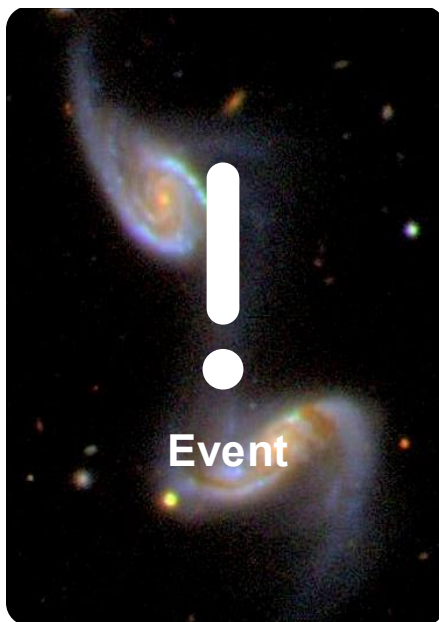
ToO

Gravitational Wave Event

Spend 3 hours of dark
time to receive

15 points

If you observe this card
keep it until the end of the
game. Otherwise discard it



Observatory

Great Conditions

An unusually calm atmosphere and clear skies mean that your observations are even more efficient than usual. Add 20% to all the numbers of objects you observe this month. Round up to the nearest hundred for each type of object.

Observatory

Robot Error

Some of the robots that position the fibers on your spectrograph have failed. Lose 1/3 of the objects you observe on all nights this month (round your remaining objects up to the nearest 100 objects)

Observatory

Observatory Dog

Bonsai, the observatory dog, comes to visit. This doesn't change your observations, but you feel better petting the good boy.

Observatory

Observatory Dog

Bonsai, the observatory dog, comes to visit. This doesn't change your observations, but you feel better petting the good boy.

Observatory

BEAR!!!!!!

A hungry bear is ransacking the observatory kitchen, evacuate now! Lose all of your observing time on the middle night

Observatory

Red Monster

A strange instrument error known as the red monster has affected your red spectrograph. You may not observe red objects on the right-most night.

Observatory

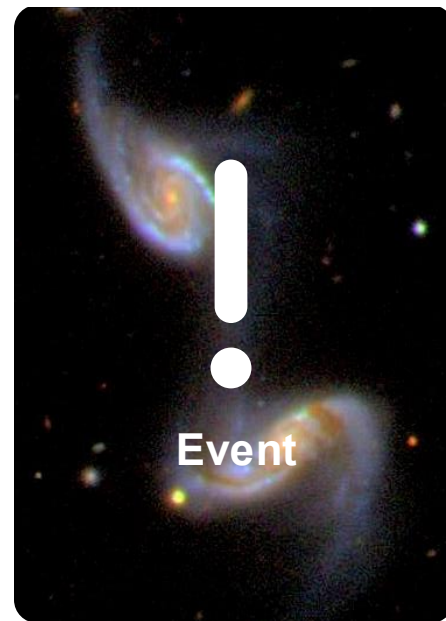
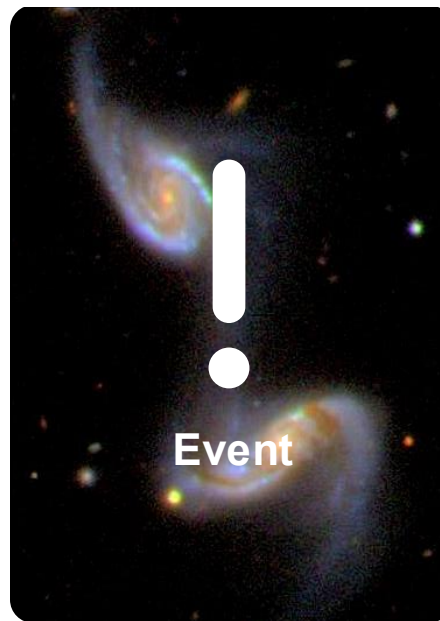
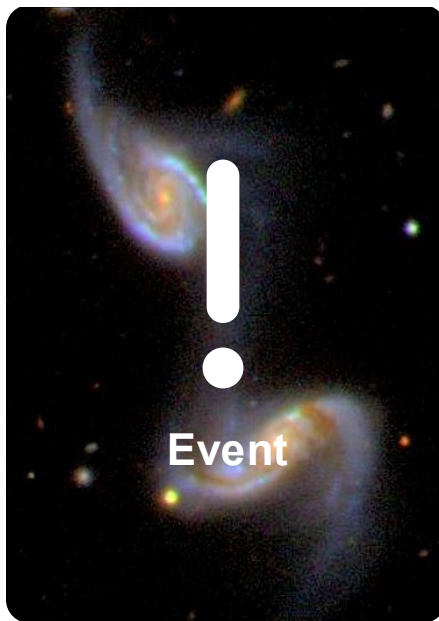
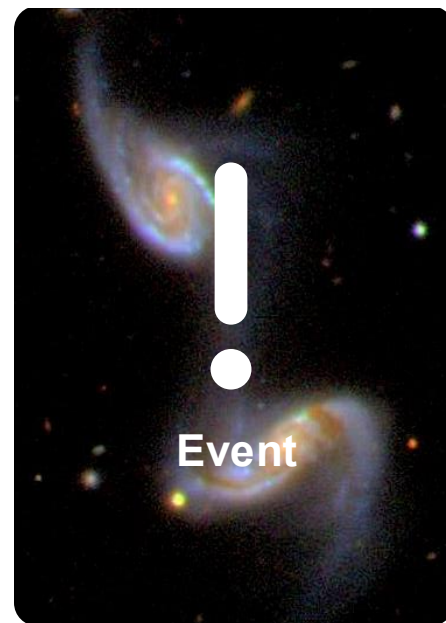
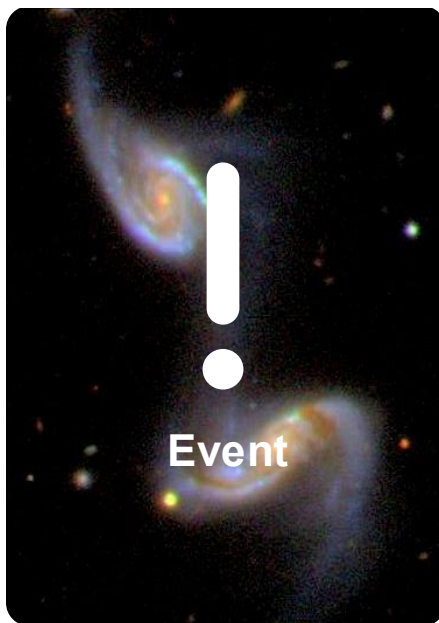
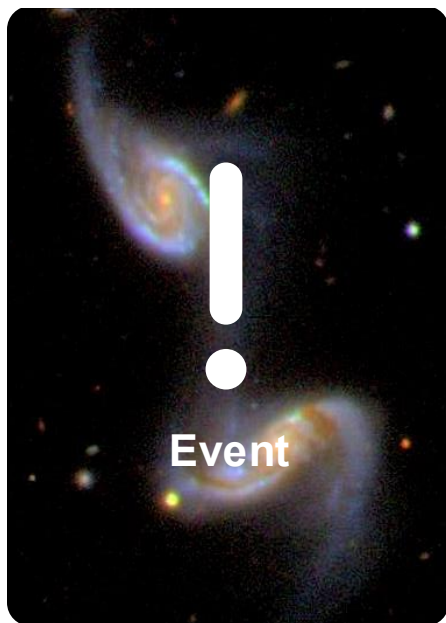
Moth Infestation

Your blue spectrograph is infested with moths. You may not observe any blue objects on the left-most night

Observatory

Observatory Dog

Bonsai, the observatory dog, comes to visit. This doesn't change your observations, but you feel better petting the good boy.



Weather

Weather

Weather

Weather

Thick Cloud

Lose all of your
observing time on the
left-most night

Thick Cloud

Lose all of your
observing time on the
left-most night

Thick Cloud

Lose all of your
observing time on the
right-most night

Thick Cloud

Lose all of your
observing time on the
right-most night

Weather

Weather

Weather

Weather

Thick Cloud

Lose all of your
observing time on the
middle night

Thick Cloud

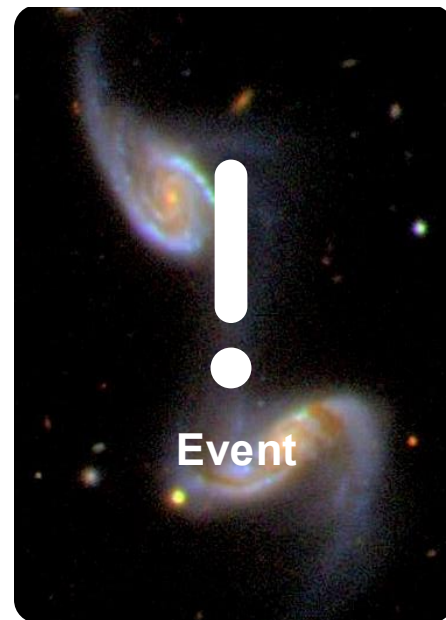
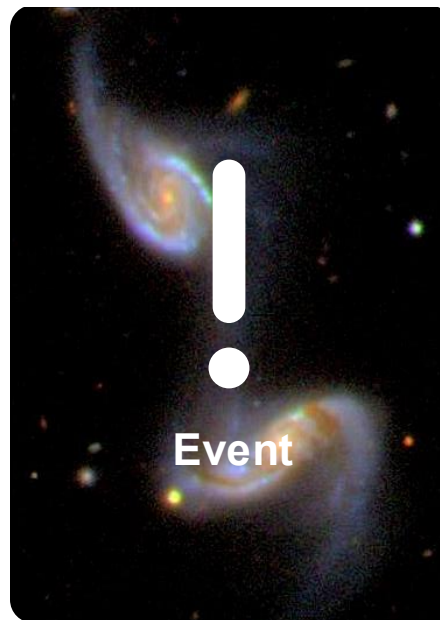
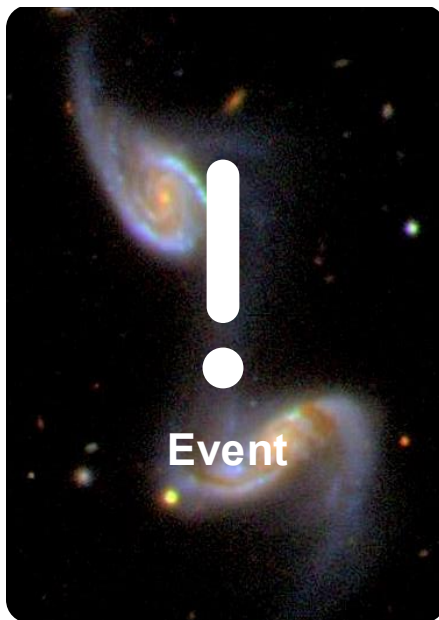
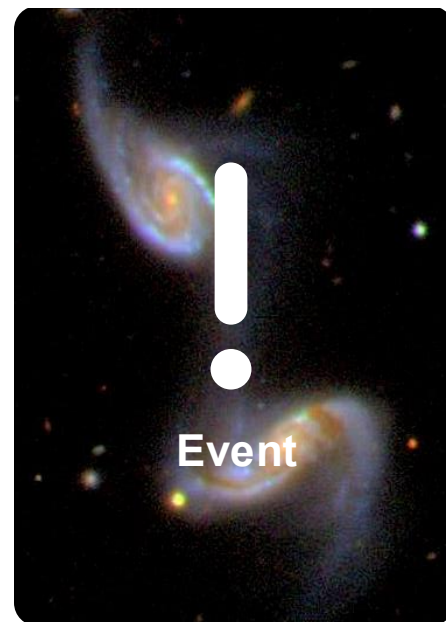
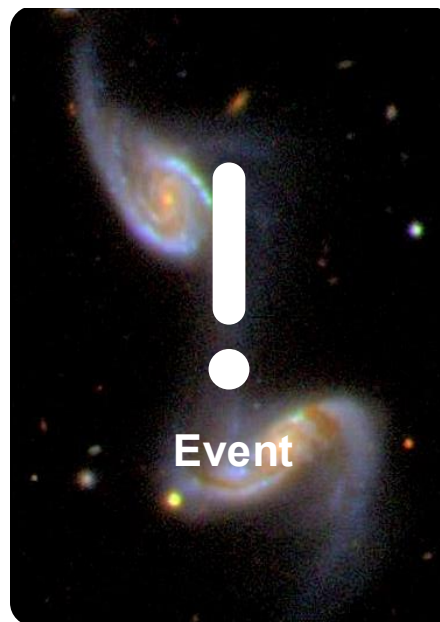
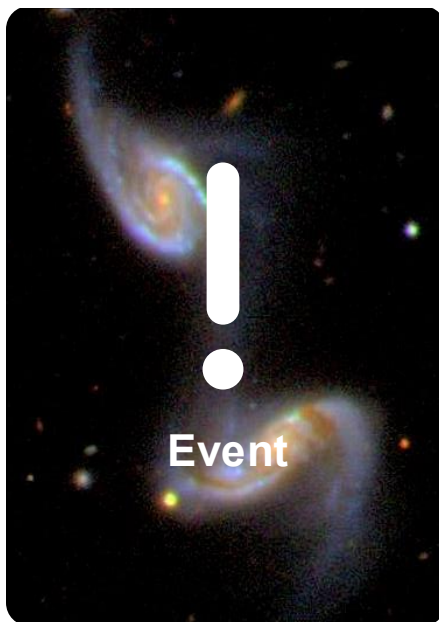
Lose all of your
observing time on the
middle night

Constant Cloud

Lose all of your
observing time this
month

Constant Cloud

Lose all of your
observing time this
month



Weather

Weather

Weather

Weather

Patchy Cloud

Lose 50% of your
observing time on the
left-most night (round
your remaining
observing time up to
the nearest hour)

Patchy Cloud

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observing time on the
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Patchy Cloud

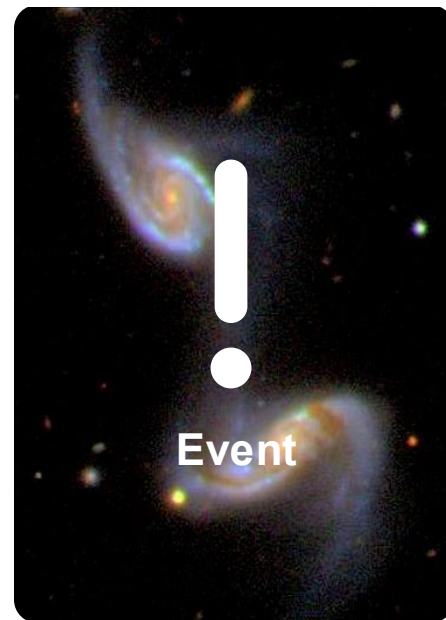
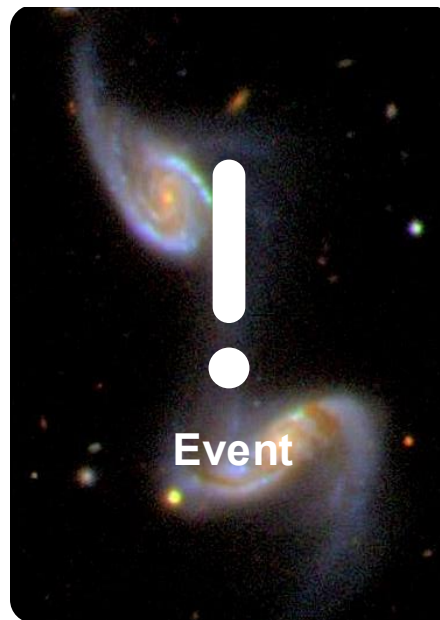
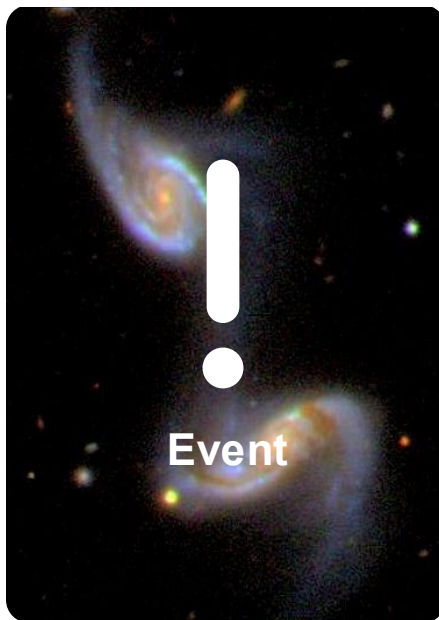
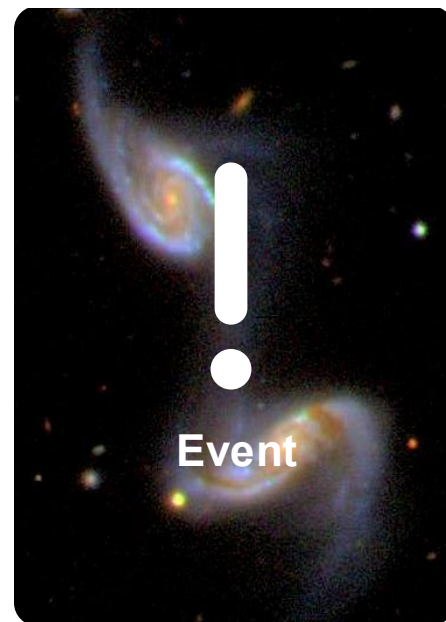
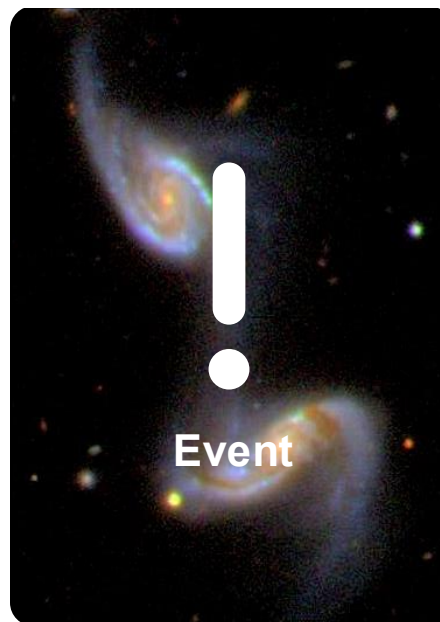
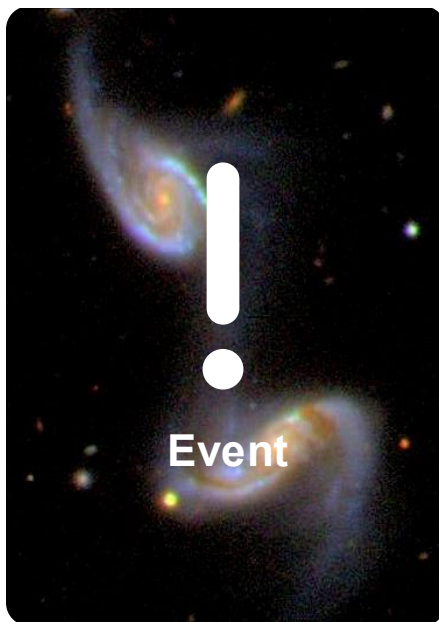
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Patchy Cloud

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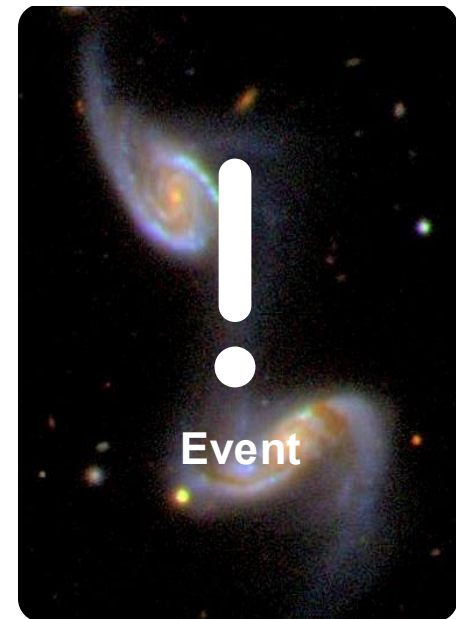
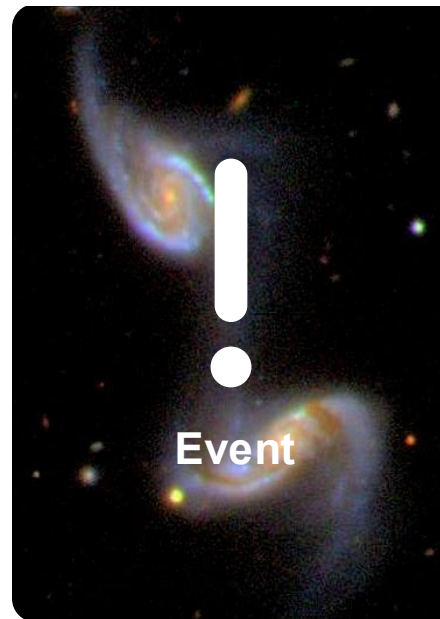
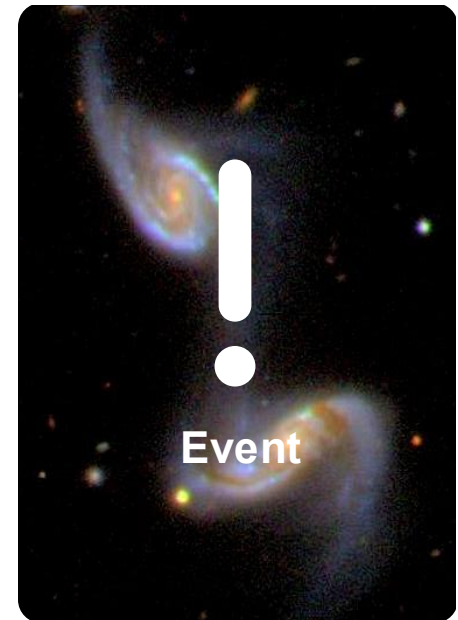
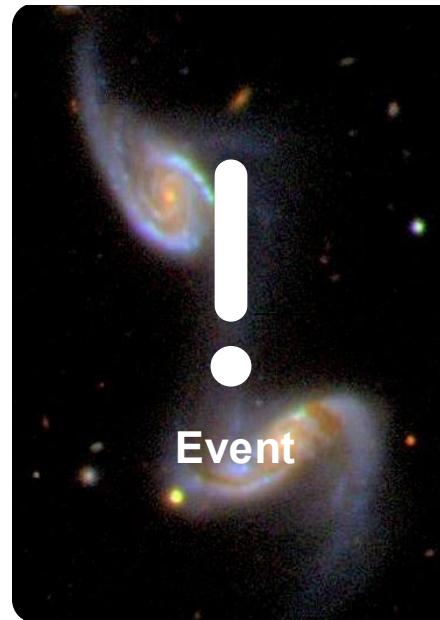
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Observatory*

Snow Storm

A huge snow storm is approaching the observatory, everyone must evacuate. All players lose all their time from all of their nights this month.

Observatory*

Hard Drive Error

The hard drive you stored some of your data on has crashed. Lose 50% of the objects you observed in the previous month. If you draw this in month number one ignore this card

White Dwarfs

faint and blue

The glowing remnants of dead stars can be used to trace the history of our galaxy.

Observing
1 hour dark time → 500
1 hour bright time → 200

Scoring
1 point per 400

Nearby Quasars

bright and blue

The huge churning disks of hot gas orbiting black holes are the brightest objects in the universe.

Observing
1 hour dark time → 1000
1 hour bright time → 400

Scoring
1 point per 800

Observatory*

Classification Error

The algorithm you used to select objects in the previous month had an error in it and you observed the wrong types of object. Switch the numbers of objects you observed last month as follows

white dwarfs → nearby quasars
nearby quasars → white dwarfs
distant quasars → red giants
red giants → distant quasars

If you draw this in month number one ignore this card

Observatory*

Great Conditions

An unusually calm atmosphere and clear skies mean that your observations are even more efficient than usual. Add 20% to all the numbers of objects you observe this month. Round up to the nearest hundred for each type of object.

Distant Quasars

faint and red

The hot disks around black holes shine like beacons in the furthest reaches of the cosmos.

Observing
1 hour dark time → 500
1 hour bright time → 400

Scoring
1 point per 500

Red Giants

bright and red

These bright stars at the end of their lives can be used to map the structure and chemical history of the galaxy.

Observing
1 hour dark time → 1000
1 hour bright time → 800

Scoring
1 point per 1000



Science Goal



Science Goal



Science Goal



Science Goal



Science Goal



Science Goal



Science Goal



Science Goal

Cosmological Mapper

Observe at least 10,000 nearby quasars and at least 5,000 distant quasars

15 points

Nearby Universe Mapper

Observe at least 15,000 nearby quasars

10 points

Distant Universe Mapper

Observe at least 9,000 distant quasars

10 points

Quick Reactions

Observe at least 2 targets of opportunity

10 points

All

Galactic Mapper

Observe at least 10,000 red giants and 5,000 white dwarfs

15 points

Galactic Archeologist

Observe at least 7,500 white dwarfs

10 points

Galactic Structure Mapper

Observe at least 18,000 red giants

10 points

Legacy Survey

Observe the broadest range of objects.

20 points