

# Today

A little more scale...

The Scientific Method

Naked Eye Observations:  
the Appearance of the Sky

# Astronomy covers astronomical scales:

- The Universe is MUCH larger than
    - Galaxies which are MUCH larger than
      - Stars which are MUCH larger than
        - Planets which are MUCH larger than
          - » Moons, comets, and asteroids, which are MUCH larger than
            - PEOPLE
- The Universe is incredibly ancient
  - but does have a finite age
    - the oldest stars are ~13 billion years old
    - the sun, earth, & solar system are 4.5 billion years old
    - new stars are still forming today

# The Scientific Method

## A few necessary ASSUMPTIONS:

- There exists an objective, knowable Reality
  - or at least an inter-subjective reality upon which independent observers can agree
- Reality is governed by physical processes that can be described by a set of rules
  - The “Laws of Nature”
- The Laws of Nature are accessible to human knowledge through experimentation
- The Laws of Nature are universal
  - The rules don’t change arbitrarily
  - God doesn’t cheat

## The idealized scientific method:

- Based on proposing and testing hypotheses

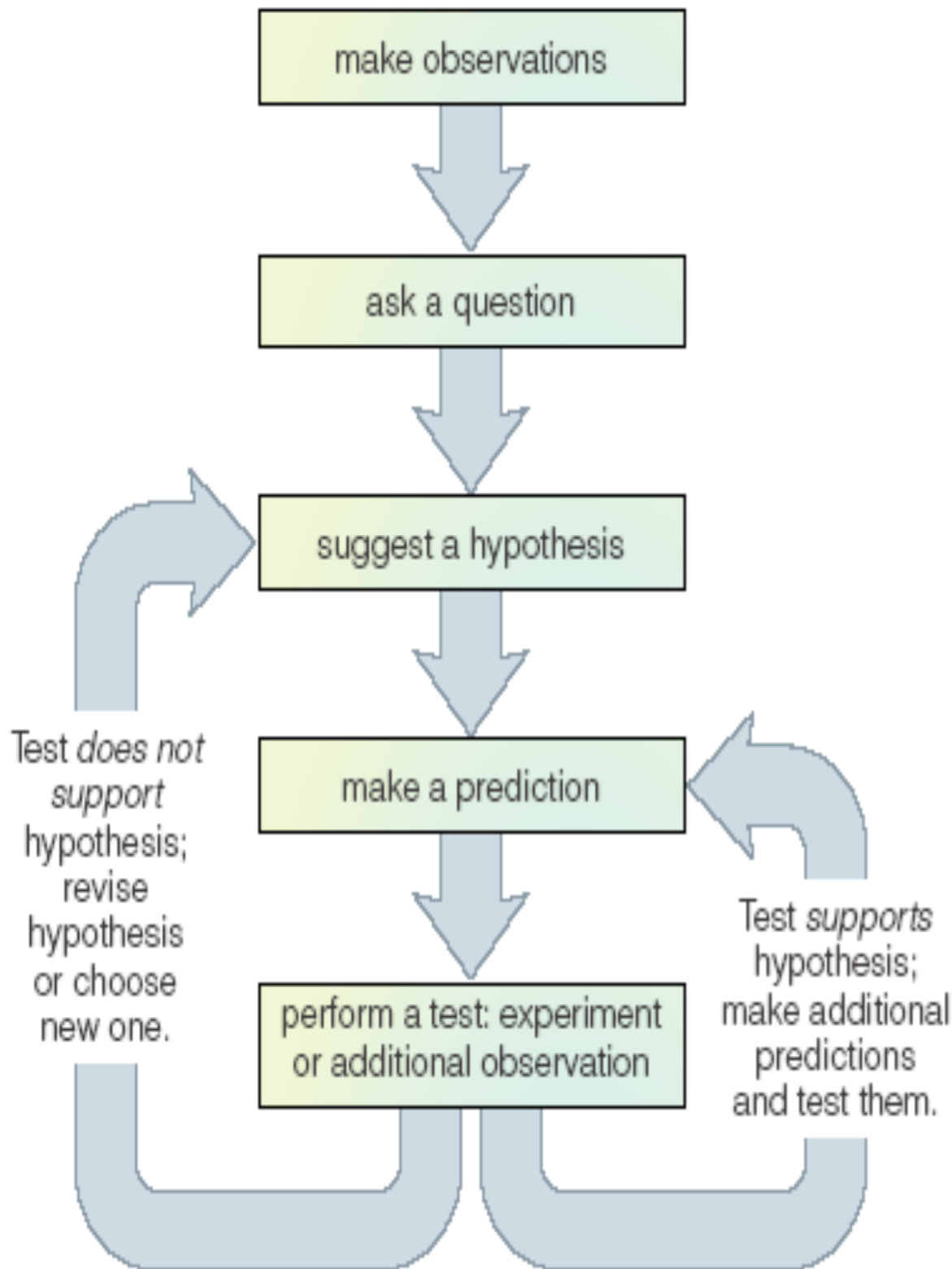
**Facts** are the results of observation or measurement.

A scientific **hypothesis** is an idea that leads to testable or falsifiable predictions.

A **theory** is a well-developed group of ideas that is tied to known physical laws and makes testable predictions.

Well-established theories (e.g., Darwin's theory of evolution, Einstein's theory of relativity) have passed many tests and are widely accepted

but theories remain subject to revision or rejection if they fail to explain new tests.

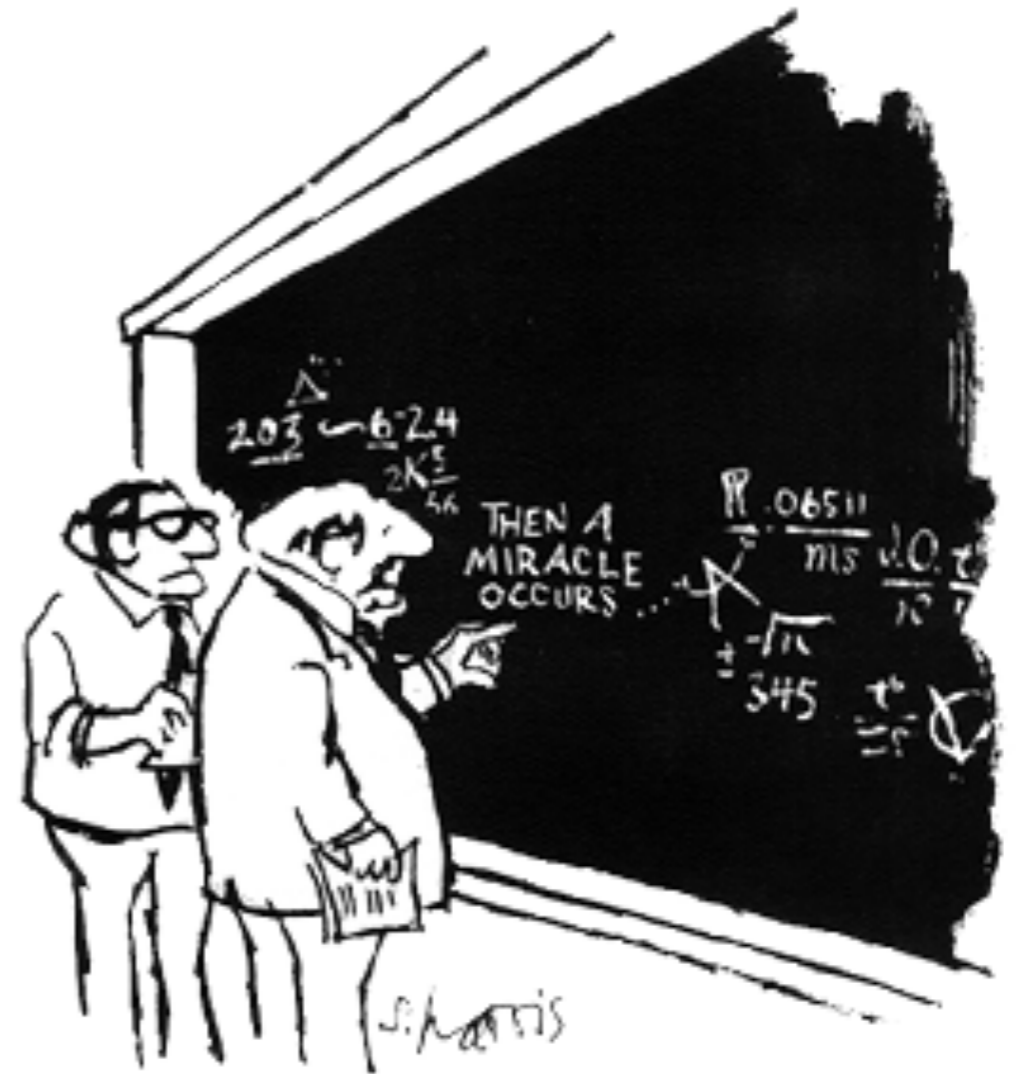


# *Hallmarks of Science: #1*

Modern science seeks explanations for observed phenomena that rely solely on natural causes.

(A scientific model cannot include divine intervention.)

No magic!



"I think you should be more explicit here in step two."

## *Hallmarks of Science: #2*

Science progresses through the creation and testing of models of nature that explain the observations as simply as possible.

This philosophy of simplicity is often called “Occam’s razor”



**“All things being equal, the simplest solution tends to be the best one.”**

**William of Ockham**

(1285 - 1347)

## *Hallmarks of Science: #3*

A scientific model must make testable predictions about natural phenomena that would force us to revise or abandon the model if the predictions do not agree with observations.

# Hypothesis Testing

Observed Reality

Theoretical Interpretation

Natural Phenomena

Hypothesized Explanation

Predictions

Experimental Tests

Ambiguous  
result

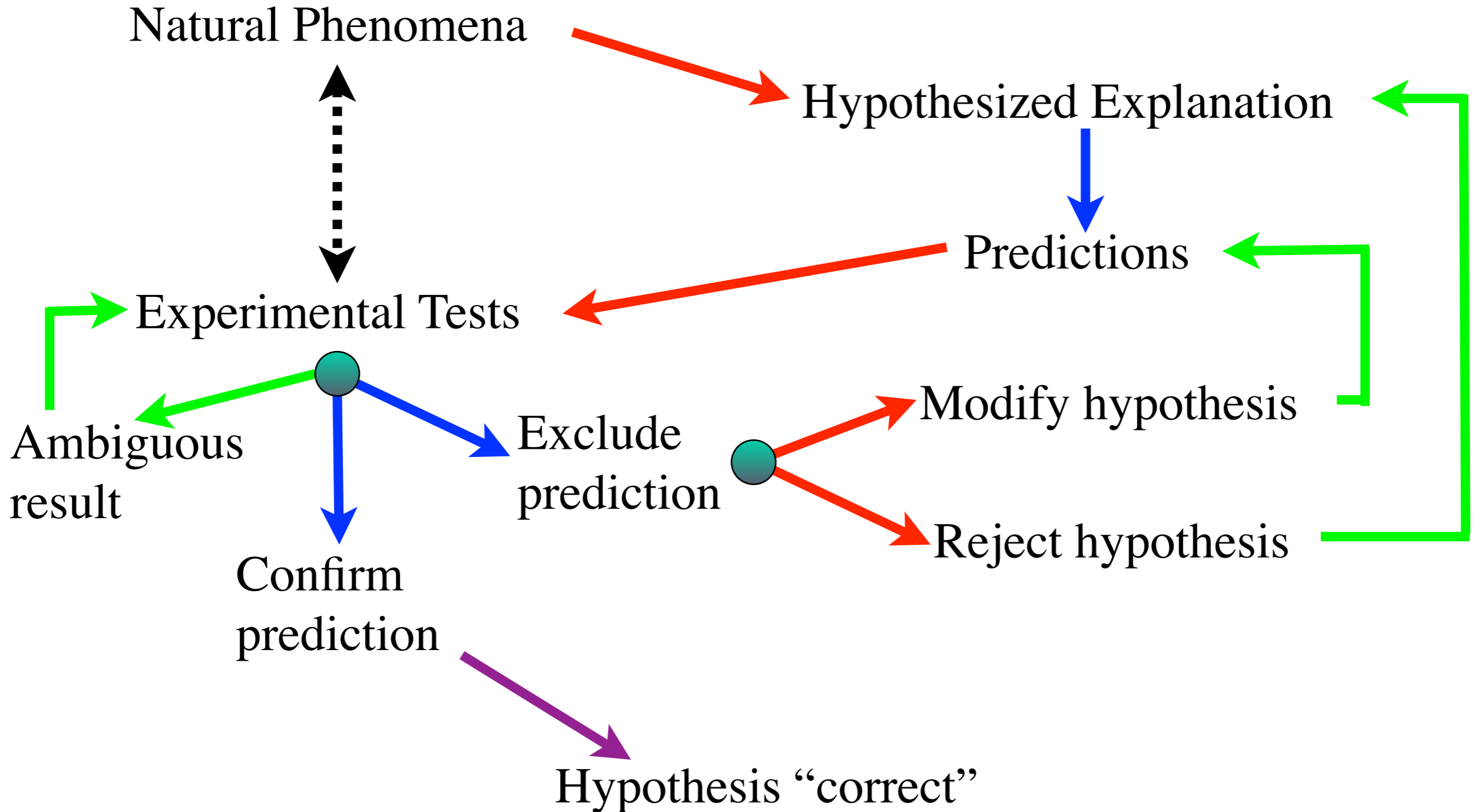
Exclude  
prediction

Modify hypothesis

Reject hypothesis

Confirm  
prediction

Hypothesis "correct"





# The Principle of Doubt

- Hypotheses can be *rejected* but never completely *confirmed*.
- At best, a theory can be *adequate* for describing a specific set of phenomena.
- Do not trust - verify through experiment.
- Simple theories are preferable to complicated theories (Occam's Razor)
  - Any theory can be made complicated enough to explain anything
  - Elegance and Understanding better than Age and Authority
  - If a theory has its predictions come true, we are obliged to acknowledge its efficacy, even if it means rejecting something we formerly believed.

# Measurement Uncertainty

- No experiment is perfect
- Experimental uncertainty is often the difference between rejecting a hypothesis and an ambiguous result
- It is important to quantify both measurements **AND** their accuracy

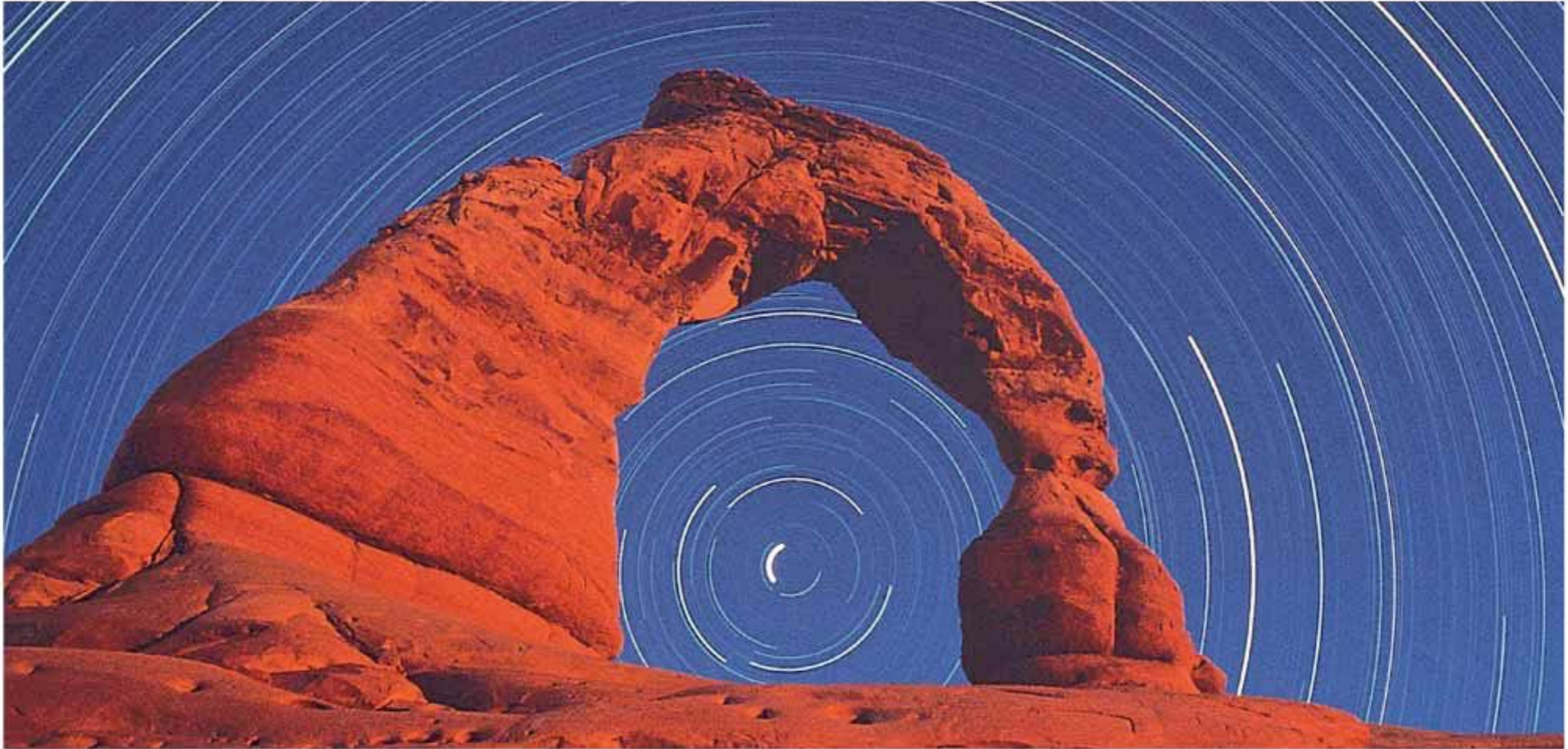
e.g., Newton's constant:

$$G = (6.67428 \pm 0.00067) \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}. \quad (0.01\%)$$

the distance to the center of the Milky Way

$$R_0 = 26,000 \pm 2,000 \text{ light years} \quad (8\%)$$

# The Appearance of the Sky



## 2.1 Patterns in the Night Sky

### Our goals for learning:

- What does the universe look like from Earth?
- Why do stars rise and set?
- Why do the constellations we see depend on latitude and time of year?

# What does the universe look like from Earth?

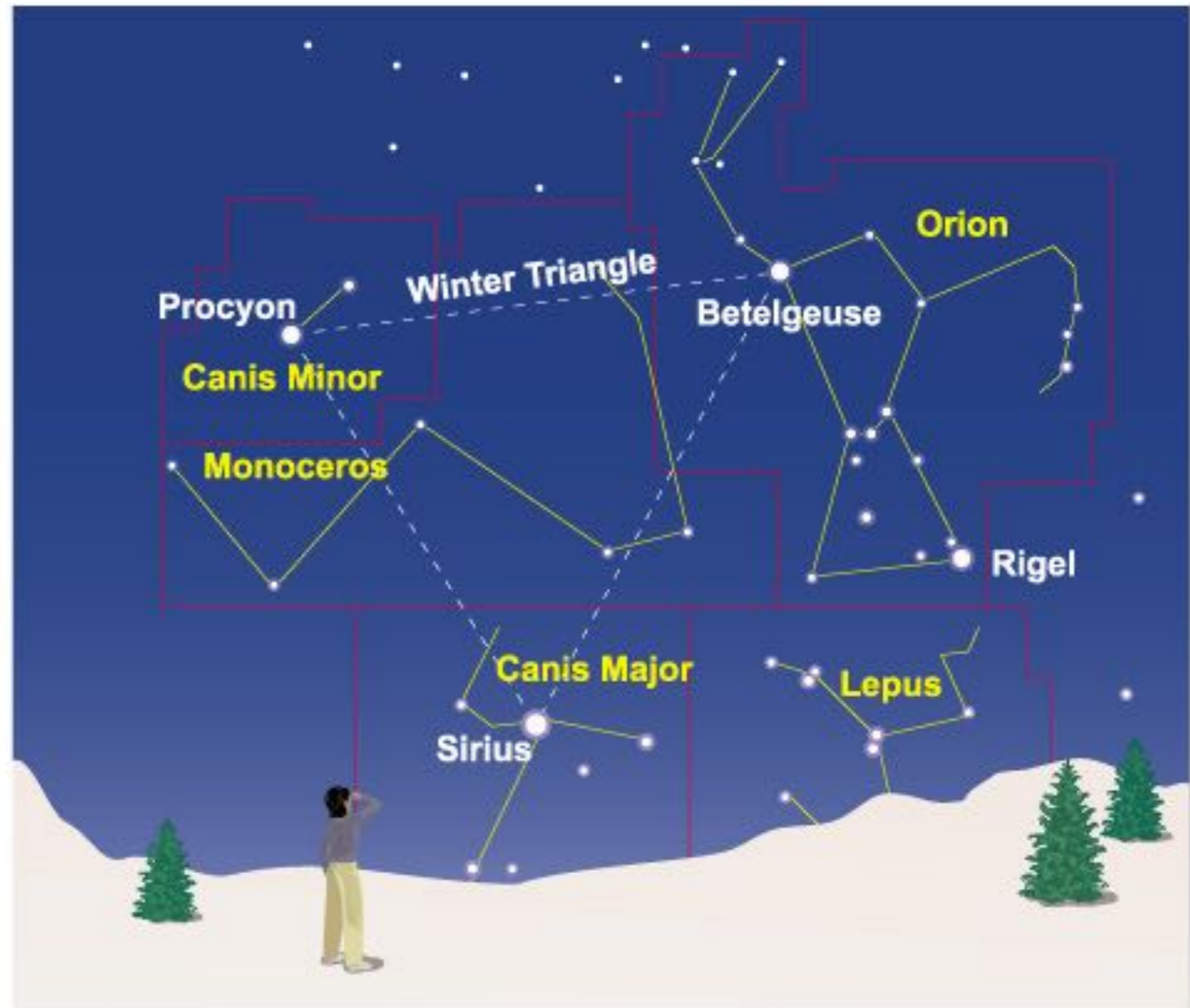
With the naked eye, we can see more than 2,000 stars as well as the Milky Way.

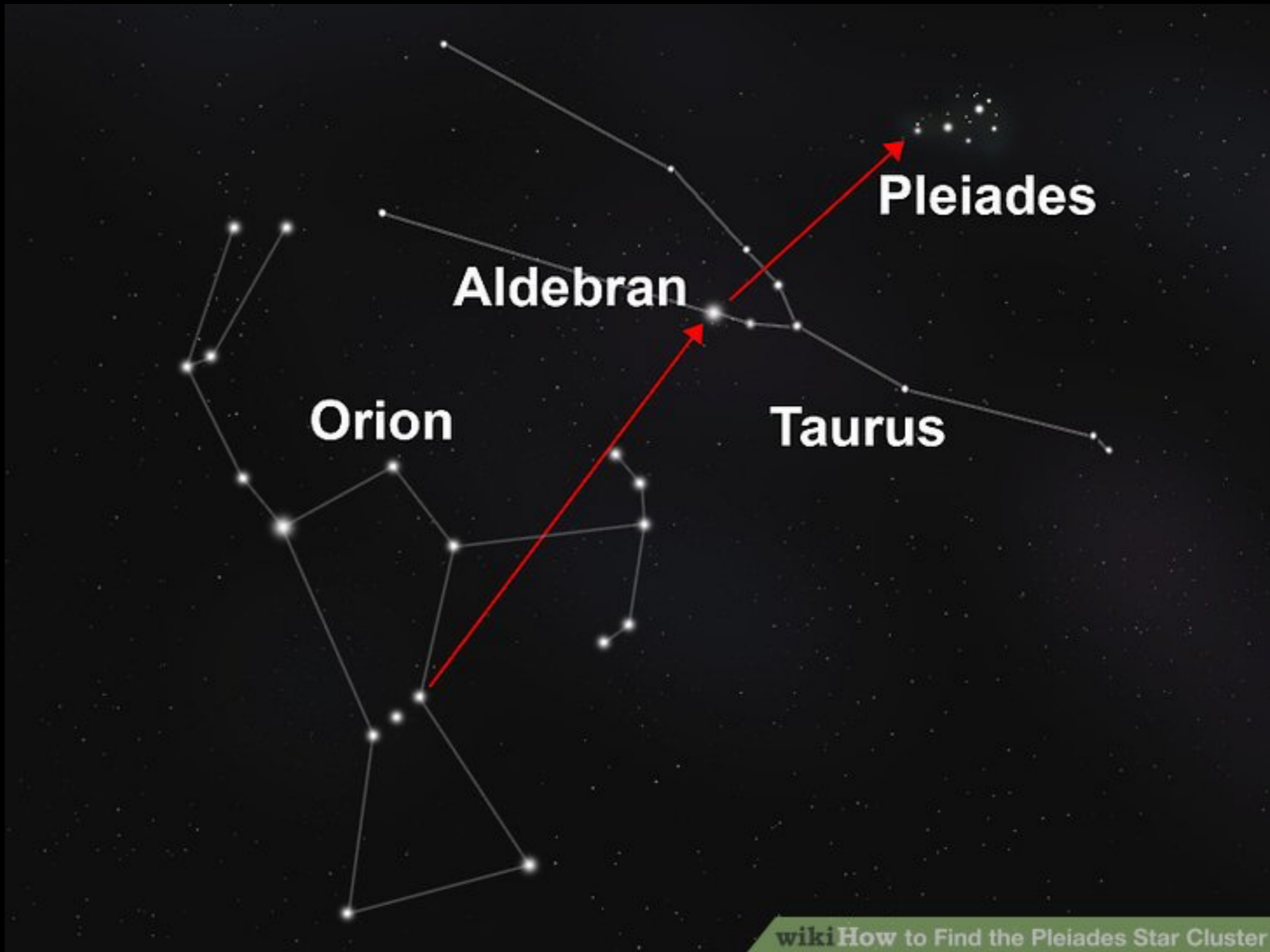


# Constellations

A constellation is a *region* of the sky.

88 constellations fill the entire sky.





**Orion**

**Aldebran**

**Taurus**

**Pleiades**



Sirius



Orion's Belt



Aldebaran

Hyades



Pleiades



tonight

**Jan 16-17**

*Around 8 pm*

Pleiades

TAURUS

Moon  
Jan 16

Moon  
Jan 17

Aldebaran

**Looking Southeast, high in the sky**

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Saturday morning

**Dawn, Jan 19**

*1 hour before sunrise*

Venus

Jupiter

Antares

SCORPIUS

**Looking Southeast**

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