FOR THE FAMILY OF: ____________________

INVESTIGATING

Astronomy

CONNECTIONS

Investigating Stars

The creation of the expanding nebula shown in this image was recorded by Chinese astronomers in 1054 AD...

See story on page 2.

INSIDE THIS ISSUE!

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Decoding Life Cycles

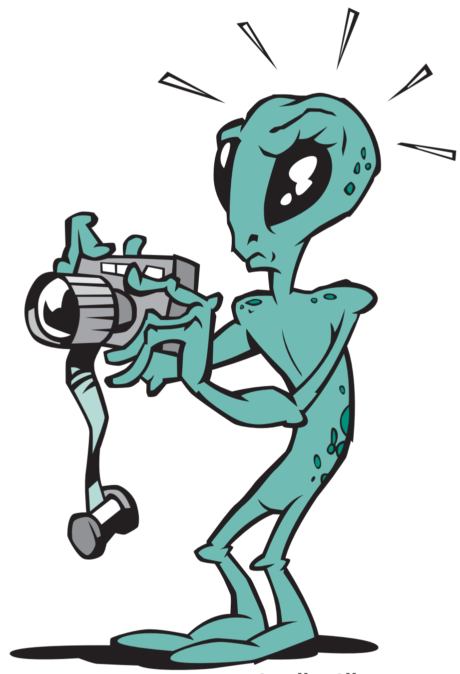
Decoding the stages in the life of some living things can be challenging, especially if those stages are very different — like an egg, tadpole, and frog; or an egg, caterpillar, cocoon, and butterfly. But time is often on the biologist's side. If a group of eggs is found, the eggs can be observed, and what comes out of them can be tracked through each stage. Time, however, is not so kind to astronomers. Stars live for millions or billions of years — far longer than the astronomers who observe them. In this two-part activity, you first play the role of "aliens," here on Earth for a short while, trying to decode the stages of the human life cycle from a set of pictures. Then you apply the same reasoning as you become astronomers, trying to decode the stages in the life cycles of stars from a set of astronomical images.

Part 1

Pretend for the next few moments that you are "aliens" visiting Earth for a very short while. You've observed a wide variety of life forms. One in particular, whose activities seem to have an impact on all the others, interests you the most. Let's call them "humans." You've collected a number of images of these humans as part of a research project. Note: While collecting these images, you [the aliens] recorded data (including size) and got a sense of what is truly the human body vs. the "accessories" and other material objects that humans wear, touch, and operate (e.g., clothing, tools and/or toys). In addition, you made a number of observations of how different types of humans interact. Make use of this knowledge as you work.

Your First Challenge:

Now that you have found this particular life form to be of special interest, you are going to try to determine the various stages of its life cycle. Unfortunately, you are not visiting Earth long enough to follow a single specimen from birth to death, but you've been observing and collecting pictures and information on a variety of humans for sufficient time to form some ideas. Can you put the pictures in order from earliest life stage (youngest) to latest life stage (oldest)? It would also be helpful to list the characteristics that you used to determine your order.



Credit: Clipart.com

On the Cover

Very massive stars die dramatic deaths called supernova explosions. The release of energy at the time of such an explosion can mean that a single star will outshine an entire galaxy. The nebula in this image resulted from just such an explosion. It was recorded as a "new star" by Chinese astronomers in 1054 AD. It outshone every star in the sky for months and was even visible in the daytime sky. (Credit: NASA)

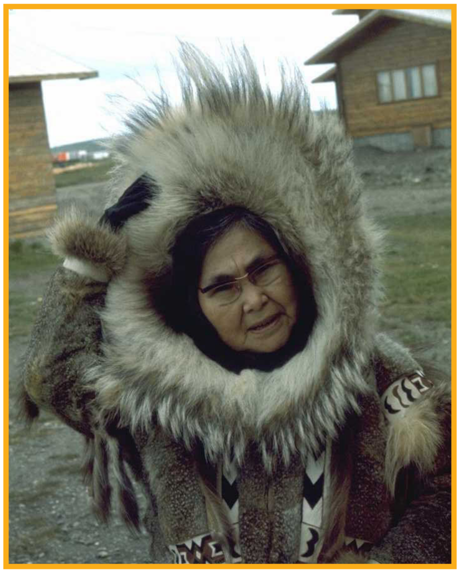


Figure 1

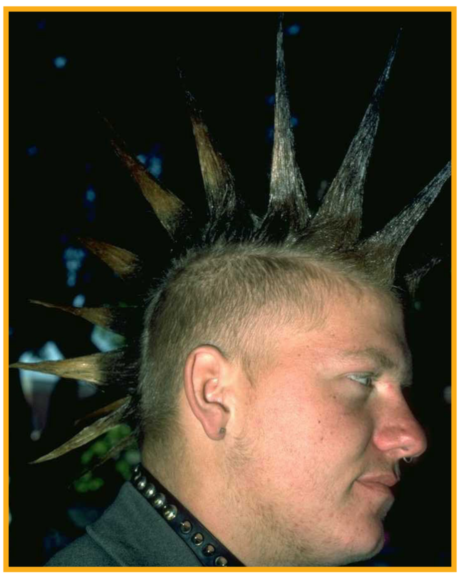


Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

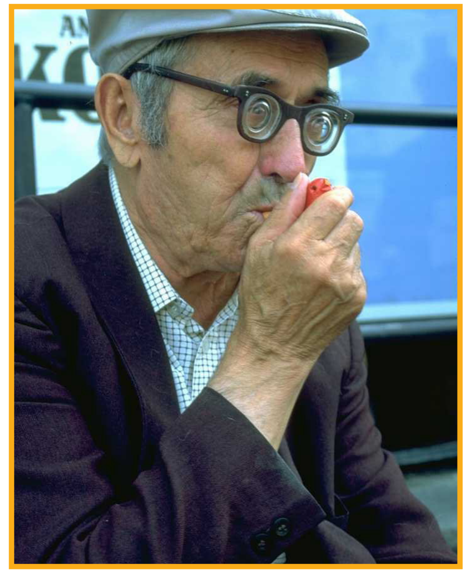


Figure 7

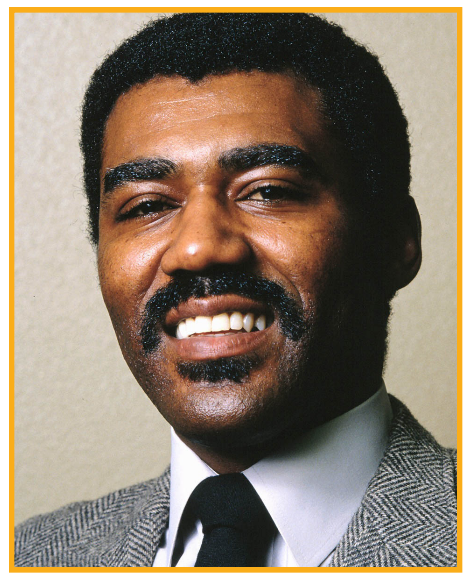


Figure 8

Credit: ASP

Part 2

Now pretend that you are an astronomer. No astronomer has been alive long enough to witness a star's birth, life, and death. We see a sky filled with stars, but how can you tell how old they are? Where did they come from, and will their light ever burn out? Astronomers have several ways of collecting clues to the answers to these questions about the lives of stars. They have telescopes and instruments like CCD cameras and spectroscopes that give them pieces to the puzzle in addition to the tools of math and physics.

Your Second Challenge:

Examine the images that follow and order them so that they demonstrate the life stages of a star. The clues that we have are:

1. Stars don't seem to form by themselves, but in groups.
2. Many stars seem to have planets in orbit around them.
3. As they age, stars expand and become unstable.
4. Unstable older stars may blow off outer layers (smaller stars—with a gentle burp, larger stars—as a dramatic supernova) to try to regain some stability.

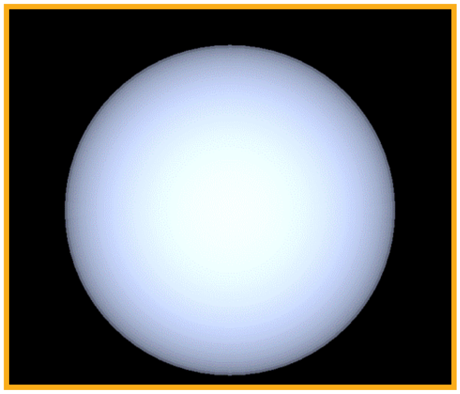


Figure 1 (Credit: NSO)

Figure 4 (Credit: NASA)

Figure 2 (Credit: NASA)

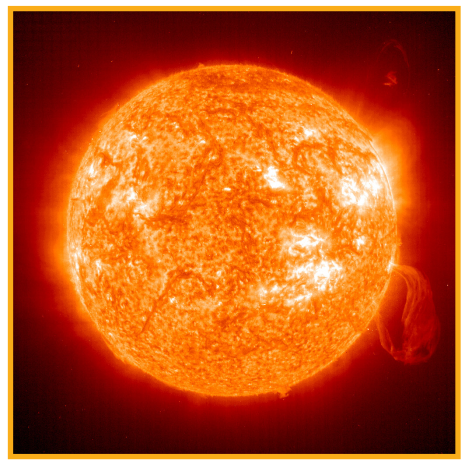


Figure 5 (Credit: NSO)

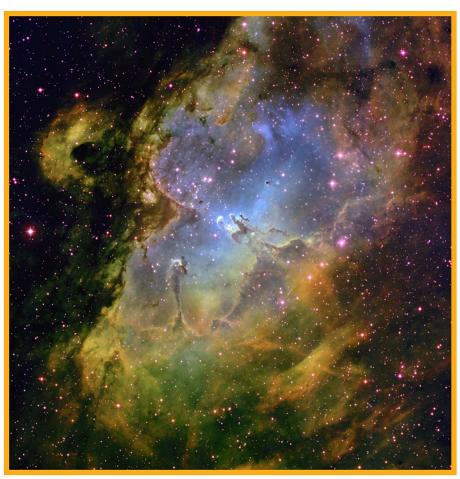


Figure 3 (Credit: NASA)

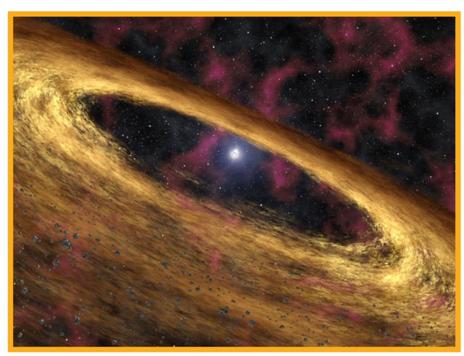


Figure 6 (Credit: JPL/Caltech)

The Stellar Zoo

All stars, with the exception of our sun, appear as pinpoints of light in the night sky. At first glance, all the stars seem to be about the same. A closer look reveals an amazing diversity of star colors and brightnesses. The color of stars is determined by their temperature—hot stars are blue or white; cooler stars are yellow and red.

Using our largest telescopes, astronomers have only directly measured the diameters of a handful of stars. But using principles of physics, we can estimate stars' sizes and compare them. In this activity, we'll compare of star sizes using a lemon to represent our sun.

Our sun is a huge ball of hot gas, over one hundred times larger than Earth. Place a lemon on a table as a model of the sun. To represent Earth at this scale, you would need to cut out the dot on top of an "i" and place it next to the lemon.

Use the diameters of the stars listed to match the size of stars in the stellar zoo with some common objects. In this model, the sun will be the size of a lemon (5 cm in diameter). Place the objects that you have on hand next to your model sun.

At this scale, the nearest star (Proximi Centauri) to our sun would be 1451 km or 870 miles away! No material object of any size lies between them. Space is truly vast and almost

Two cool stars (left and right lower corners) with a cluster of hot stars. (Credit: NASA)

Table of Star Diameters

Star Name	Type of Star	Diameter (suns)
Sirius B	white dwarf companion of Sirius	0.05
Proxima Centauri	red dwarf	.25
Sun	yellow	1
Procyon	yellow star in Winter Triangle	2
Sirius	white star in Winter Triangle	2
Trapezium Stars	very hot blue stars in Orion Nebula	10
Polaris (North Star)	yellow giant star in the Little Dipper	30
Rigel	hot white star in Orion	70
Betelgeuse	red supergiant star in Winter Triangle	650

Table of Common Object Sizes Compared to the Sun

Object	Approximate Diameter (cm)
grain of sand	0.025
dot of an i	0.050
peppercorn	0.30
coffee bean	1.0
acorn	2.0
cherry tomato	2.5
lemon (our sun)	5.0
grapefruit	10
cantaloupe	15
volleyball/bowling ball	20
small car	350
SUV	500
House	1500
high school football stadium	10,000

Answer Key for Challenge

The correct sequence of images that describe the life of a star is:

1) Figure 3: Stars begin their lives in vast clouds of gas and dust called nebulae. They form in clusters and usually appear as white stars surrounded by wisps of gas.

2) Fig. 6: Stars form by gravity drawing particles together until the star is large enough and hot enough to begin fusing hydrogen into helium. The left over material forms smaller clumps of material—planets and moons.

3) Fig. 5: Our sun (image is taken in ultraviolet wavelengths) has been shining steadily for the past 4.6 billion years. It should continue to bathe Earth with its light and heat for another 4 billion years or so.

4) Fig. 2: Stars like our sun become bloated red giant stars as internal fusion processes cause instability in the star, causing its outer layers to expand.

5) Fig. 4: An older star throws off gas from its surface forming a nebula around the star. By shedding its outer layers, the hot central core is gradually revealed.

6) Fig. 1: Small stars like our sun will end their lives as white dwarf stars about the size of Earth. Cooling slowly, these stars will lose their energy over billions of years, and only a black chunk of carbon will be left of the once-dynamic star.

Star Witness

Dr. Aparna Venkatesan, University of San Francisco

Tackling physics and math, subjects that do not generally inspire passion, Aparna Venkatesan feels fortunate to specialize in a subject that inherently touches on topics that dazzle the imagination. Astronomy uses the tools of astronomy to answer the big questions faced by humans: Where do we come from? What are we made of? What is the fate of our planet? Of the universe? Dr. Venkatesan feels it's her duty not just to educate people, but "to open hearts and minds to what we know about the universe and the world."

Her love of learning and sense of service were instilled in her by her parents, and by the age of eight, she knew that she wanted to be an astronomer. She recalls, "I felt a deep wonder and awe of the night sky and also a great love of mathematics, and astronomy seemed a natural choice: the principles of mathematics taken to the grandest possible scale."

Dr. Venkatesan attended school in Singapore and India before studying astronomy at Cornell University (home of Cosmos author, Carl Sagan) in Ithaca, New York. She went on to get her doctorate in astrophysics from the University of Chicago. Having completed a postdoctoral fellowship and teaching at the University of Colorado, she is now an Assistant Professor at the University of San Francisco.

Credit: A. Venkatesan

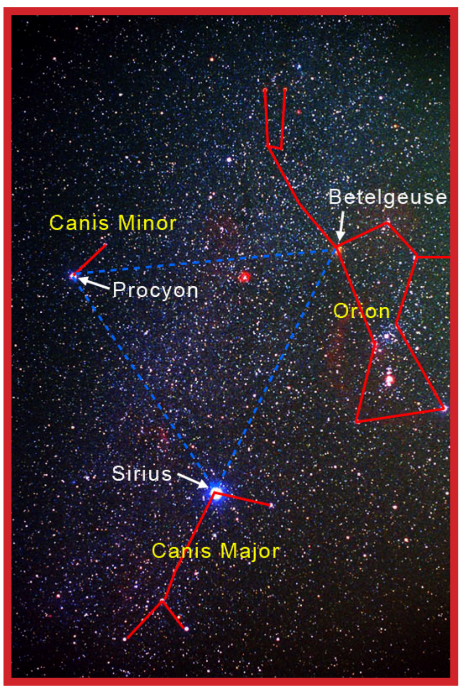
She is working to expand the university's astronomy course offerings and to establish a minor in the discipline. She is also interested in developing courses in archeoastronomy (the study of the astronomy of ancient peoples), astrobiology (the study of the origins of life and the conditions needed for it), and cosmology (the study of the evolution of the universe).

Dr. Venkatesan's research has been not as a theoretician, not an observational astronomer, so computers, not telescopes, are her tools. She develops and models theories about what the first stars were made of, how they evolved and died, and how they influenced the environment of the early universe. Dr. Venkatesan believes it's important to study the stars. In her own words, "We and everything we are made of were created in the interiors of stars or in their death throes as supernovae, so in a very real sense, we are studying ourselves when we study the stars. The first stars are especially interesting to me, as they have a unique primordial composition that leads to their having distinctive observational signatures. The important question is how long they could have existed in the early universe and whether we can eventually detect them." ★

Sky Watch

Have you ever heard the story of why Orion the Hunter and Scorpius the Scorpion are on opposite sides of the sky? It has to do with the scorpion stinging and killing the mighty hunter as punishment for his boasting. That would seem a good reason for Orion to want to stay as far away from Scorpius as possible, even for eternity. Such ancient stories can help you remember how the constellations are arranged in the sky.

Another way to get to know the night sky is to navigate by "landmarks," using bright stars and simple phrases like "follow the arc to Arcturus". Here, we'll examine some of the stars of winter and decode the stories the stars have to tell us (instead of the stories we may have told about them!).



Credit: Greg Kuchmek

The Winter Triangle includes the brightest star from each of three constellations—Orion the Hunter, Canis Major the Great Dog, and Canis Minor the Lesser Dog. The stars are Betelgeuse, Sirius, and Procyon, respectively. Just by looking at those three stars, can you make some guesses about how far away they are? Not surprisingly, the closest is the brightest, but the dimmest is not the farthest. Check out the table below to see how distant each is compared to our sun; you may not have realized how much closer to us Sirius is than any other star in the winter sky. Betelgeuse is much farther away than the other two in the Winter Triangle—can you guess why it's still so bright? To find out take a look at the Stellar Zoo activity in the Family Features section.

Once you've located those three stars on the star chart or in the actual night sky, you can use them as a guide to find several other constellations and bright stars. Starting at Sirius, hop to Betelgeuse, then hop again about the same distance in the same direction, and the bright star you'll find is Capella, shining with a golden glow like our sun. Capella is a multiple star system, so you're actually seeing the light of nine stars—the two largest are similar to our sun (only a bit bigger). Capella is the brightest star in Auriga, the Charioteer. To find the rest of him, look for a pentagon shape, a 5-sided box. One of those corners (the one opposite Capella) is the brightest star in Taurus—its red eye, Aldebaran. Given Aldebaran's brightness, can you tell if it's as far away as Betelgeuse or as close as Procyon? Check the table to find out.

Star Name	Distance
Sun	8 light-minutes
Betelgeuse	429 ly
Sirius	8.6 ly
Procyon	11 ly
Pleiades	440 ly
Hyades	156 ly
Capella	45.2 ly
Castor	50 ly
Pollux	34 ly
Aldebaran	65 ly

Recall that the pattern of stars that makes up Orion is a rectangle, with the three belt stars in the center. Betelgeuse in our Winter Triangle is in the northwest corner, but down in the southeast corner is the brilliant bluish Rigel. If you draw a diagonal line from Rigel through Betelgeuse and follow the line, you'll come to two stars that are nearly equal in brightness. These are the stars marking the heads of the Gemini Twins, Castor and Pollux. The dim stars that trickle back to Orion's shoulder mark the bodies of the Twins. Would you guess that Castor is actually a six-star system, half again as far away as Pollux?

Following the Belt of Orion in either direction will lead you to some interesting treasures. Looking down and to the left, you will come upon Sirius, the brightest corner in our Winter Triangle. If you go up from the belt from right to left, though, you'll find two amazing clusters of stars. The first takes on the shape of a "V" and is called the Hyades. It marks the face of Taurus the Bull. If you continue along that line, you'll come to the Pleiades, a little swarm of stars riding on the shoulder of the Bull. Both of these star clusters are relatively young and have taught us something about how to measure the distances to stars.

The brightest star in Taurus is Aldebaran. It's at the top of the V in the Hyades, but is not a part of the cluster. Aldebaran is less than half that distance away from us and is huge, about 95 times the diameter of our sun. ★

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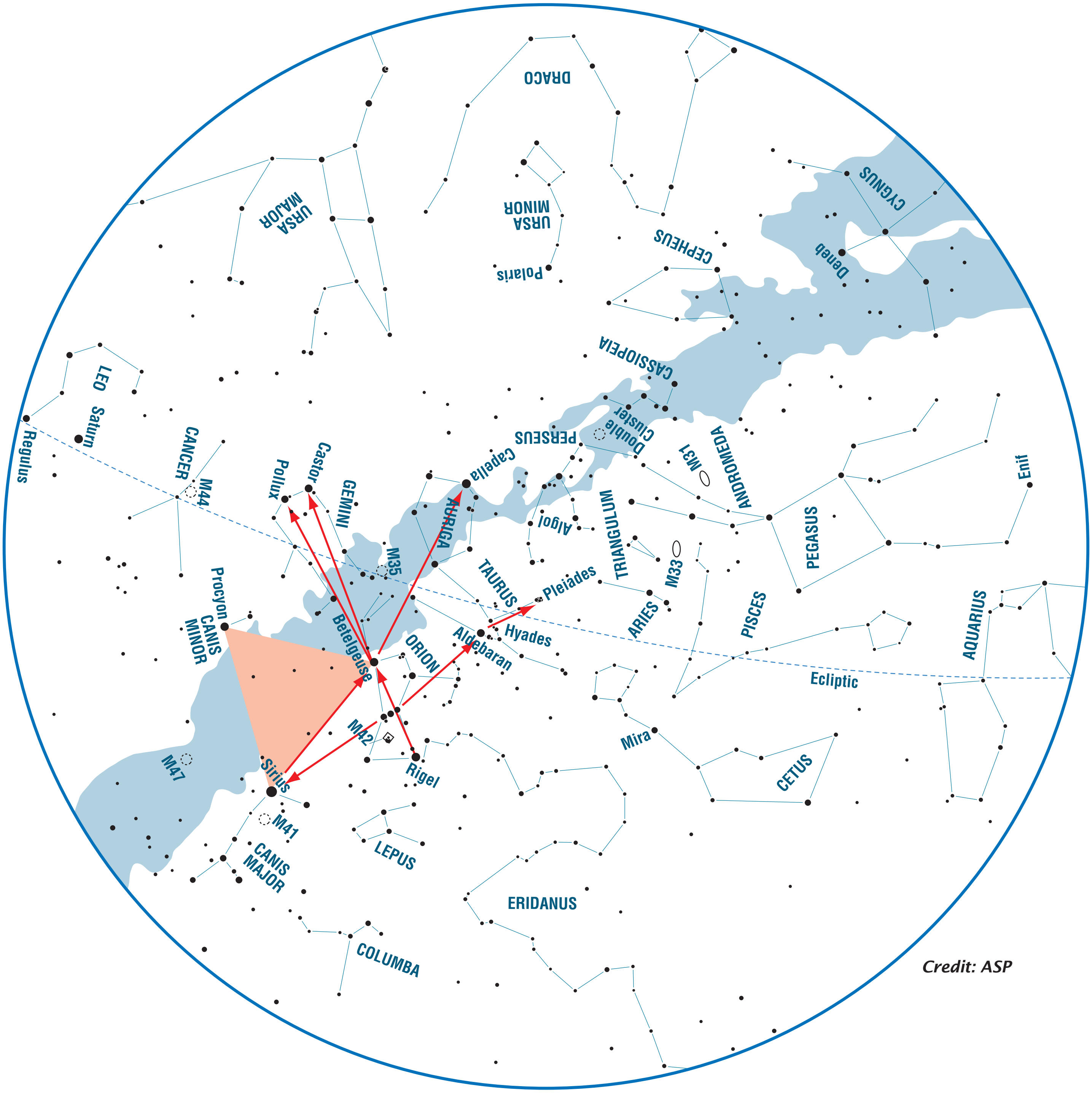
DRACO
URSA MAJOR
URSA MINOR
Polaris
CEPHEUS
CYGNUS
Deneb
CASSIOPEIA
Double Cluster
PERSEUS
M31
ANDROMEDA
LEO
Regulus
Saturn
CANCER
M44
Pollux
Castor
GEMINI
Capella
AURIGA
Algol
TRIANGULUM
M33
PEGASUS
Enif
M35
TAURUS
Pleiades
ARIES
PISCES
AQUARIUS
Procyon
CANIS MINOR
Betelgeuse
ORION
Aldebaran
Hyades
Ecliptic
M42
Rigel
Mira
CETUS
M47
Sirius
M41
CANIS MAJOR
LEPUS
ERIDANUS
COLUMBA

Credit: ASP

Cultural Connections

As you begin to consider the stars in the sky, one of the first things you encounter are great names! The planets (other than Earth) are named for Roman gods and the constellations are mostly from Greek mythology, but many of the star names are more ancient than that. For some people these names may be tongue twisters, for others they are old friends. Below is a list of unusual names that perhaps sound nonsensical at first. But most are actually from the Arabic language and are quite descriptive of the part of the constellation that they mark.

A single star may be known by several different names. It could have a catalog name, which is usually just a number. A star listed in the Smithsonian Astrophysical Observatory catalog would be designated by a number preceded by "SAO." Betelgeuse is also known as SAO 113271. Stars can also have a letter of the Greek alphabet in its name, like alpha, beta, or zeta. That's only true for the brightest stars in any constellation. If its name contains alpha, then the star is the brightest in that constellation. Another name for Betelgeuse is alpha Orionis. Some stars, usually only the brightest, also have proper names, and this is where the tongue-twisting begins.

Try these out for starters:

Alpheratz — Navel of the horse — Alpha Andromedae

Algol — the demon star, or the Ghoul — Beta Persei

Betelgeuse — Armpit of the Central One (from the Arabic: Ibt al Jauzah) — Alpha Orionis

Capella — She Goat — Alpha Aurigae

Deneb — Tail — Alpha Cygni

Deneb Kaitos — Tail of the Whale towards the South — Beta Ceti

Denebola- Tail of the Lion — Beta Leonis

Polaris- Pole Star — Alpha Ursa Minoris

How'd you do? Ready to take on some tough ones?

Zubenelgenubi — The Southern Claw — Alpha Librae

Zubeneschamali — The Northern Claw — Beta Librae

Although today the above two stars are part of the constellation of the scales, Libra, their names reveal that, on more ancient star maps, they once were a part of Scorpius, the Scorpion.

And the all-time tongue twister is not of Arabic origin. It can be found in Taurus, the Bull: Shurnarkabti-sha-shutu.

Try it again, slowly... (shur — nar — kab- ti —sha- shu- too).

This wonderful star, otherwise known as Zeta Tauris, has a name that is Babylonian for "the star in the Bull towards the South" (not to be confused with Shurnarkabti-sha-iltanu, "the star in the Bull towards the North"). It marks the tip of the more southerly horn of Taurus. ★

Talk Like an Astronomer

light-year: The distance light travels in a year, nearly 6 trillion miles.

light-minute: The distance light travels in a minute, 11,160,000 miles.

nebula: A cloud of gas and dust in space.

For more on these wonderful names and where they came from, read the classic STAR NAMES: Their Lore and Meaning, by Richard Hinckley Allen. Originally the book was published in England in 1899, but it was republished and updated by Dover Publishing and is still in print.

You can also go to James Kahler's Star of the Week site for lots of fun star information:

Hot Link [http://www.astro.uiuc.edu/%7Ekaler/sow/sowlist.html]