Chapter 5: Introducing the Variable Star Astronomy Constellations

Petroglyph in 9 Mile Canyon, Utah depicting Coyote Scattering the Stars in the Sky

Introduction

Early observers organized stars into easily recognizable patterns that resembled the objects, animals, and people important to their survival and religions. We now call these patterns constellations. From our perspective here on Earth, it appears that the stars in any given constellation are connected in some way, that they all occupy the same part of space, and are all the same distance from the Earth. However, in reality, most stars within constellations are up to several light- years away from each other. An example is the Big Dipper. Alkaid, the star at the end of the handle, is 100 light-years away from Earth. The next handle star is actually two stars that appear very close together. The brighter star, Mizar, is 78 light-years away from Earth, and Alcor is 81 light- years away. Mizar and Alcor are 3 light-years apart in the sky, a distance of 27 trillion kilometers, and Alkaid and Mizar are 22 light-years apart, a distance of 198 trillion kilometers! An exception is the Pleiades, the "Seven Sisters" asterism. The Pleiades is an open cluster, a group of stars born together in the same stellar nursery and now slowly drifting apart.

The constellation names and boundaries we recognize today were officially established in 1930 by the International Astronomical Union (IAU). The entire sky is now partitioned into 88 irregularly-shaped pieces, and one constellation is assigned to each piece.

The history of constellations, of who named them, and when, is full of myth, rumor, and ambiguity. Surviving records are contradictory and few, and open to interpretation. Some can be traced back to a particular origin; others only hint at their beginnings. Decoding the past—through rock art, paintings, stone monuments, and oral story-telling traditions that were written down only in more recent times—is a challenging task. Such artifacts and ancient records can be translated or interpreted in a variety of ways. Sometimes one constellation has one story, sometimes it has several stories or myths.

Sometimes the same story can have several different variations. We will never know the actual sources of many constellation names and myths: they are lost in time. However, one possible key to the antiquity of a particular constellation with its associated mythology is the amount of sky which it covers—with the earliest occupying large portions of the sky, and more recent constellations occupying smaller portions, though this is not always the case.

A few bright stars associated with every constellation have been named by different cultures. European and Arabic culture names were assigned by early Roman, Babylonian, Greek, Sumerian, and Arab astronomers. Other cultures, such as Native American and Chinese, have their own names for the same stars. Star names have meanings rooted deep within each culture; however, it would be bewildering if different cultures continued to use their own names for the same star. The inconsistency of star names necessitated the development of a more systematic method of nomenclature, or naming. We now use brightness as the criterion to label stars within any given constellation. The star with the brightest apparent magnitude in each constellation is named "alpha," followed by the possessive form of the Latin name for the constellation; the second brightest, "beta," the third brightest, "gamma," and so on down through the Greek alphabet. For example, the most common name for the brightest star in the constellation Auriga is "Capella," although it has been given other names by other cultures. The scientific name of this star is "alpha Aurigae" or just "α Aurigae," or even ""α Aur" ("Aur" being the abbreviation for Auriga). This system of naming stars is the one most commonly used by astronomers. Since there are more stars in a constellation than letters in the Greek alphabet, several different naming systems take over after the last Greek letter is used. One of these systems will be presented in Chapter 6. Below are listed the possessive forms and abbreviations for the constellations presented in this chapter, and the Greek alphabet for your reference in naming the stars within the constellations.

CONSTELLATIONS

Name	**Possessive Form**	**Abbreviation**
Auriga	Aurigae	Aur
Cassiopeia	Cassiopeiae	Cas
Cepheus	Cephei	Cep
Cygnus	Cygni	Cyg
Ursa Major	Ursa Majoris	UMa

GREEK ALPHABET

α alpha	η eta	ν nu	τ tau
β beta	θ theta	ξ xi	υ upsilon
γ gamma	ι iota	ο omicron	φ phi
δ delta	κ kappa	π pi	χ chi
ε epsilon	λ lambda	ρ rho	ψ psi
ζ zeta	μ mu	σ sigma	ω omega

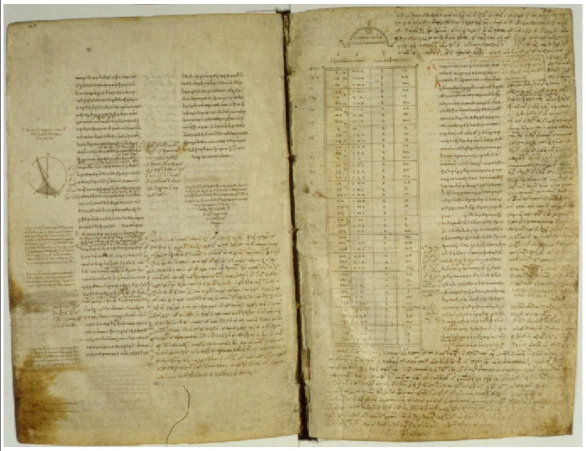
Whatever the mythologies associated with the constellations, the stars and other celestial objects they contain are very real. For centuries, the constellations have guided ancient explorers and travelers over unknown lands and uncharted seas. We are now going to investigate five constellations: Auriga, the Charioteer; Ursa Major, the Big Bear(containing the famous asterism the Big Dipper); Cygnus, the Swan; Cepheus, the King of Ethiopia; and Cassiopeia, the Queen of Ethiopia. They are full of spectacular sights and contain many interesting objects, including variable stars. Many contain deep-sky objects, such as globular clusters, galaxies, and nebulae, which come in different sizes, brightnesses, shapes, and colors.

Investigation 5.1: The Magnitude of Stars in a Constellation

Your instructor will show you a slide of one of the constellations mentioned in the introduction. Sketch the main stars of the constellation pattern, remembering that the brighter the star, the larger the point. Label the brightest star as alpha, then continue ranking the brightness of the stars using the sequence of Greek letters in the table above. How does your diagram compare with those of the rest of the class? Does everyone agree on the ranking of magnitude?

How Do You Keep Track of the Stars?

You may live under city lights and can see only a few of the brightest stars, or you may live farther out in the suburbs or in the country and can see hundreds of stars. If you are in a place that has very dark skies, you may be able to see, with your unaided eye, about 3000 individual stars from where you stand. Use binoculars or a small telescope, and the number increases to many thousands of stars. How do you keep track of what you have seen? What happens when you start recording what you see in the sky?



Part of a manuscript copy of Ptolemy's star catalogue in The Almagest.

The more information you collect about the stars, the more you need to keep it arranged in some systematic way. When you make a list of the stars you observe, together with your observations about the star, you are compiling information. Once your list grows to more than a few hundred items, it becomes, properly speaking, a *catalogue*.

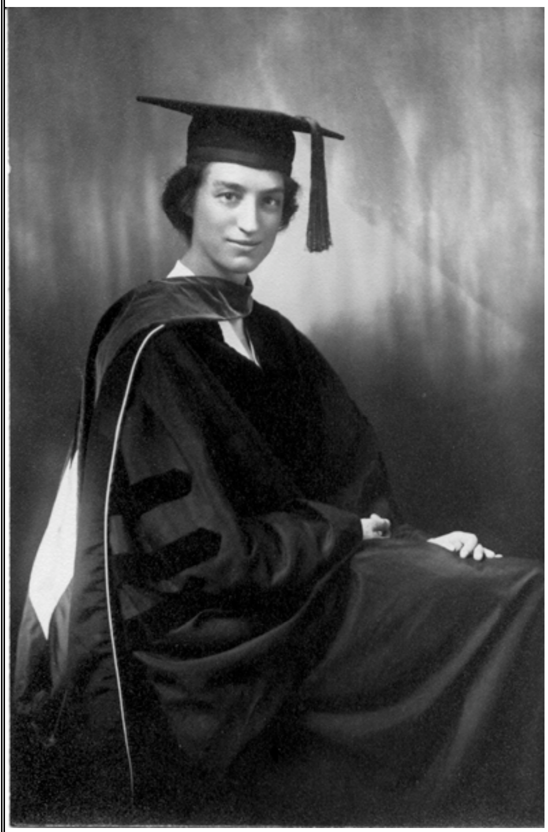
Observers of the night sky have been compiling catalogues for a long time. The earliest known star catalogue was compiled by Hipparchus; however, it is known only by references to it in other sources. The catalogue itself has long since been lost or destroyed. An early formal star catalogue is contained in a work by Claudius Ptolemaeus (Ptolemy) of Alexandria, called *The Almagest* (which is Arabic for *The Greatest*), compiled in about 140 A.D. Ptolemy's *Catalogue of Stars* comprised two of *The Almagest's* thirteen volumes. In the catalogue, Ptolemy gives the positions of 1,022 stars having magnitudes from 1 to 6.

Ptolemy's catalogue is important because it is the oldest account of positions of stars that is accurate enough to compare to modern Part of a manuscript copy of observations. Ptolemy's *Catalogue of Stars* was the only reliable and widely used listing of star positions from 138 until 1602 when Tycho Brahe published a catalogue of his own observations.

Catalogues are fundamental to the work of astronomy. Without catalogues, astronomers would very quickly lose track of new information about the stars, and would have to spend many hours in the library just to find one small fact about a star. Star catalogues are vital tools for the astronomer, and yet compiling a catalogue is work that most astronomers would shun. Researching and compiling the information of others is unglamorous work compared to searching for new stars or planets through a powerful telescope, or thinking of new theories about the origin of the universe.

HD	HR	HIP	Name	RA 2000.0 (h m s)	Dec 2000.0 (d m s)	Parallax (mas)	*V*	Spectral type and luminosity class
1461	72	1499	–	00 18 42	−08 03 11	42.67	6.46	G5 V
157 089	–	84 905	–	17 21 07	+01 26 35	25.88	6.95	G0–2 V
162 396	6649	87 523	–	17 52 53	−41 59 48	30.55	6.20	F8 IV–V
189 567	7644	98 959	–	20 05 33	−67 19 15	56.45	6.07	G3 V
193 307	7766	100 412	–	20 21 41	−49 59 58	30.84	6.27	G0 V
196 755	7896	101 916	κ Del	20 39 08	+10 05 10	33.27	5.05	G5 IV
210 918	8477	109 821	–	22 14 39	−41 22 54	45.19	6.23	G5 V

Information on 7 of the 9110 stars listed in The Bright Star Catalogue, fourth revised edition, published in 1982. This was the last edition of this catalogue to be published in the form of a book. Subsequent editions are now published primarily in a computerized format.



E. Dorrit Hoffleit, Ph.D. Radcliffe, 1938

Dr. Dorrit Hoffleit is one astronomer who has not shunned the difficult, tedious, and time-consuming work of compiling star catalogues. Even though she has been officially retired from her position as senior research astronomer at the Yale University Observatory for 20 years now, she continues to do a great deal of research work in astronomy. Dr. Hoffleit's 90th birthday was marked by the completion of the fourth edition of the *Yale Catalogue of Stellar Parallaxes.* This is a two-volume compilation of 15,994 parallaxes that were computed for 8,112 stars. These measurements are important because they tell how far away these stars are. As collaborator with Dr. William F. van Altena, the primary author, and Dr. John Truen-liang Lee, Dr. Hoffleit was mainly responsible for conducting the literature searches necessary to ensure not only that the material included in the catalogue was up to date, but also that conflicts in information about these stars would be noted and resolved.

Dr. Hoffleit was also responsible for the third, fourth, and fifth revised editions of *The Bright Star Catalogue.* Her work on these catalogues spans a period of about 30 years. *The Bright Star Catalogue* is one of the most frequently consulted reference works in astronomy. The fifth edition of *The Bright Star Catalogue* was revised on magnetic tape at the Astronomical Data Center (ADS), Goddard Space Flight Center, Greenbelt, Maryland. This catalogue, and many others like it, are now made available primarily in machine-readable form such as magnetic tapes or computer diskettes. The trend over the last 10 years or so has been to digitize as many of these standard reference catalogues as possible. This monumental task is mainly the responsibility of two agencies, the Astronomical Data Systems (ADS) of NASA, and the Centre de Données Astronomiques de Strasbourg (CDS) in France.

"These are not flashy things," van Altena says about Hoffleit's work with star catalogues. "They deal with the fundamental nature of stars. They're things that astronomy needs to make any progress toward the future. It's all very fine to make grand theories about the age, size, and origin of the universe, but if you don't know how bright or massive stars are then you're building on a house of cards."

Dorrit Hoffleit was born in Alabama in 1907. She wanted to study astronomy after she saw the collision of two meteorites in the sky above her home in rural Western Pennsylvania. She went to college at Radcliffe, and earned her doctorate in astronomy from Harvard University. Dr. Hoffleit spent the first half of her 70-year astronomy career at Harvard College Observatory, and the second half at Yale University Observatory. From 1956 to 1978 she also directed the Maria Mitchell Observatory in Nantucket, Massachusetts, where she established a program to help young women and men discover research opportunities in astronomy. Dr. Hoffleit's astronomy work is wide-ranging. The study of variable stars is one of her specialties: she discovered 500 variable stars in the constellation Sagittarius. She has also studied, researched, and written about meteors and comets, spectroscopy, astrometry, astronomy education, and history of astronomy. Her passion for work in the field of her choice eclipses the more ordinary things in her life. "Work for the work's sake," Dr. Dorrit Hoffleit says, "and it will become a part of you."

Investigation 5.2: A Study of the Constellation Auriga, the Charioteer

Auriga is a perfect example of how confusing the mythologies of a constellation can be. There are varying myths concerning the constellation itself, as well as separate stories about its brightest star, Capella. Auriga is represented as a man who has one foot on the constellation Taurus, the Bull. The star that is the tip of the left horn of Taurus is shared with Auriga. Auriga is holding a set of reins in his right hand, and carrying a female goat with two kids in his left arm. Capella represents the female goat. Since the myth surrounding Capella is so different from that of Auriga, it is possible that one myth was superimposed over another, more ancient, myth. The depiction of Auriga as a shepherd might have originated as a myth in its own right.

Auriga is associated with two separate charioteers in Greek mythology. One is the coachman Erichthonius, represented as half-man and half-serpent, who is credited as the inventor of the chariot. Another story is about Myrtilos, the charioteer of Oenomaus, the king of Elis. The king had a beautiful daughter who had many suitors. The king, however, was fearful of a prophecy that foretold of his death at the hands of his future son-in-law. He vowed his daughter would never marry. Keeping his vow a secret from his daughter, Oenomaus did not simply forbid her to wed. Instead, he said that any suitor had to win his daughter by beating him in a chariot race. If they lost, “off with their head!” The king had the best horses in the country, and Myrtilos kept them in excellent condition. The king’s daughter, whose name was Hippodameia, knew that Myrtilos was secretly in love with her. The next contestant was Pelos, with whom Hippodameia was in love. Hippodameia asked Myrtilos as a favor to loosen the bolts on the king’s chariot during the next contest. This Myrtilos readily agreed to, hoping that the princess would be grateful enough to accept him as her husband. When the loosened bolts came out of the king's chariot, the king was killed. Myrtilos tried to run away with Hippodameia, but Pelos caught up with him and cast him into the sea to his death.

Another Roman myth claims that Auriga, the crippled son of the goddess Minerva and the blacksmith god Vulcan, who was also lame, invented the chariot to make it easier for himself and his father to move around. The other gods then honored Auriga for this improved form of transportation by placing him in the sky with a wagon whip in his hand.

Capella may be associated with the Roman story of the goat named Amaltheia who provided Jupiter with milk on the island of Crete. Jupiter was the son of Saturn and Rhea, and Rhea had taken Jupiter to the island to protect him from his father, who had been known to devour his children. Several other stories equate the rising of Capella with the beginning of the new year. Capella was called Dilgan in Sumerian mythology and Dendera by the Egyptians, and both of these cultures marked their new years with the rising of Capella. Because the start of a new year is usually associated with the vernal equinox, Capella and Taurus could have been utilized as calendars in this fashion from approximately 3700 to 1700 BC. The Egyptians saw Dendera as a mummified cat carried by a man wearing feathers. In India, Capella was a god holding a string of pearls representing the changing lunar cycle.

The constellation Auriga is visible in the night sky of the Northern Hemisphere from December to February. Capella, alpha Aurigae, is actually a bright yellow double star system with a surface temperature that is the same as our Sun. It is located approximately 13 light-years from Earth. Apart from Capella and the other obvious bright stars which you drew in the previous activity, there are other interesting objects located within the constellation.

Your instructor will show you a slide of the constellation Auriga. There are some variable stars located within this constellation as well as in the other constellations in this chapter. One star that changes in brightness is epsilon Aurigae, located in the area of the goat's kids. This is not, however, a star that you want to watch through a complete cycle of change in brightness: Epsilon Aurigae is an eclipsing binary with a period of about 27 years. The supergiant being eclipsed is so large that the Sun and entire Solar System would fit inside the star! Epsilon Aurigae is 625 light-years from Earth.

Within Auriga are three open clusters of stars, M36, M37, and M38. Open clusters are groups of stars which were born together within the same cloud of gas and dust, have the same motions in space, and are held together by mutual gravitation. They have similar ages and chemical compositions, but may differ in mass, magnitude, and temperature. The open clusters are usually found in narrow regions within the spiral arms of our galaxy. The highest concentration is found along the Milky Way in the constellation Sagittarius, the direction of the galactic center.

The Aurigid meteor shower originates from the direction of Auriga, close to Capella. This shower peaks in mid-September.

Investigation 5.3: A Study of the Constellation Ursa Major, the Big Bear

Seven stars form the Big Dipper, the well-known asterism in Ursa Major, which is among the oldest recognized patterns in the sky. It is a prominent pattern of bright stars and is circumpolar for mid-northern to polar latitudes in the Northern Hemisphere. Interestingly, although the pattern represents a variety of objects to many cultures—a plow, wagon, coffin, skunk, camel, shark, canoe, bushel, sickle, even a hog's jaw—several cultures share myths concerning a bear. Archaeological evidence suggests that the stories about this constellation may date back to the Ice Age when ancient people could cross over the Bering Strait to North America. At that time, cultures in both Siberia and Alaska shared a common heritage. It is even thought possible that the constellation actually got its name 50,000 years ago when a paleolithic bear cult existed.

A recurring theme that runs through mythology is the kinship of bears and humans. Bears can lumber along on all fours, or stand up on their hind feet and gesture with their front paws. Ursa Major, in its travels throughout the heavens, constantly changes from quadrupedal to bipedal positions, seeming to run along on all fours nearest the horizon and then rising to its hind feet to begin the ascent back into the sky. There have been many fairy tales and fantasies written about people taking the form of bears. In some cultures bears are regarded as gods.

One story about the Big Bear is shared by the Micmac Indians of Nova Scotia and the Iroquois Indians along the St. Lawrence seaway. In this story, the quadrangle of the dipper represents a bear who is pursued by seven hunters; the three closest hunters are the handle of the dipper. As autumn approaches, the four farthest hunters dip below the horizon and abandon the hunt, leaving the closest three hunters to chase the bear. The hunters are all named after birds. The closest hunter to the bear is named Robin, the second closest is Chickadee, and the third is Moose Bird. Chickadee is carrying the pot in which the bear will be cooked. The second star in the handle is actually two stars, called Mizar and Alcor, which represent Chickadee and the pot. In autumn, as the bear attempts to stand up on two legs, Robin wounds the bear with an arrow. The wounded bear sprays blood on Robin, who shakes himself and in the process colors the leaves of the forest red; some blood stains Robin and he is henceforth called Robin Redbreast. The bear is eaten,and the skeleton remains traveling through the sky on its back during winter. During the following spring a new bear leaves the den and the eternal hunt resumes once more.

A Roman myth involves both bears, Ursa Major and Ursa Minor. A beautiful maiden, Callisto, hunting in the forest, grew tired and laid down to rest. The god Jupiter noticed her and was smitten with her beauty. Jupiter's wife, Juno, became extremely jealous of Callisto. Some time later, Juno discovered that Callisto had given birth to a son and decided that Jupiter must have been the father. To punish her, Juno changed Callisto into a bear so she would no longer be beautiful. Callisto's son, called Arcas, was adopted and grew up to be a hunter, while Callisto continued to live in the forest. One day Callisto saw Arcas and was so overjoyed at seeing her son that she rushed up to him, forgetting she was a bear. Arcas thought he was being attacked and shot an arrow at Callisto. Jupiter saw the arrow and stopped it from hitting Callisto. To save Callisto and her son from further damage from Juno, Jupiter changed Arcas into a bear also, grabbed them both by their tails, and swung them both into the heavens so they could live peacefully among the stars. The strength of the throw caused the short stubby tails of the bears to become elongated. Juno was even angrier at Jupiter and managed to exact still more revenge on poor Callisto and Arcas. She went to the gods of the sea and forbade them to let the two bears wade in their waters or streams on their long and endless journey around the pole star.

An Arab myth associates this asterism with a funeral. The quadrangle represents a coffin and the three handle stars are people following the coffin and mourning. The middle star (really the two stars Mizar and Alcor) represents the daughter and son of al-Naash, the man in the coffin, who has been murdered by al-Jadi, the pole star. Other cultures, too, relate funeral processions to the Big Dipper.

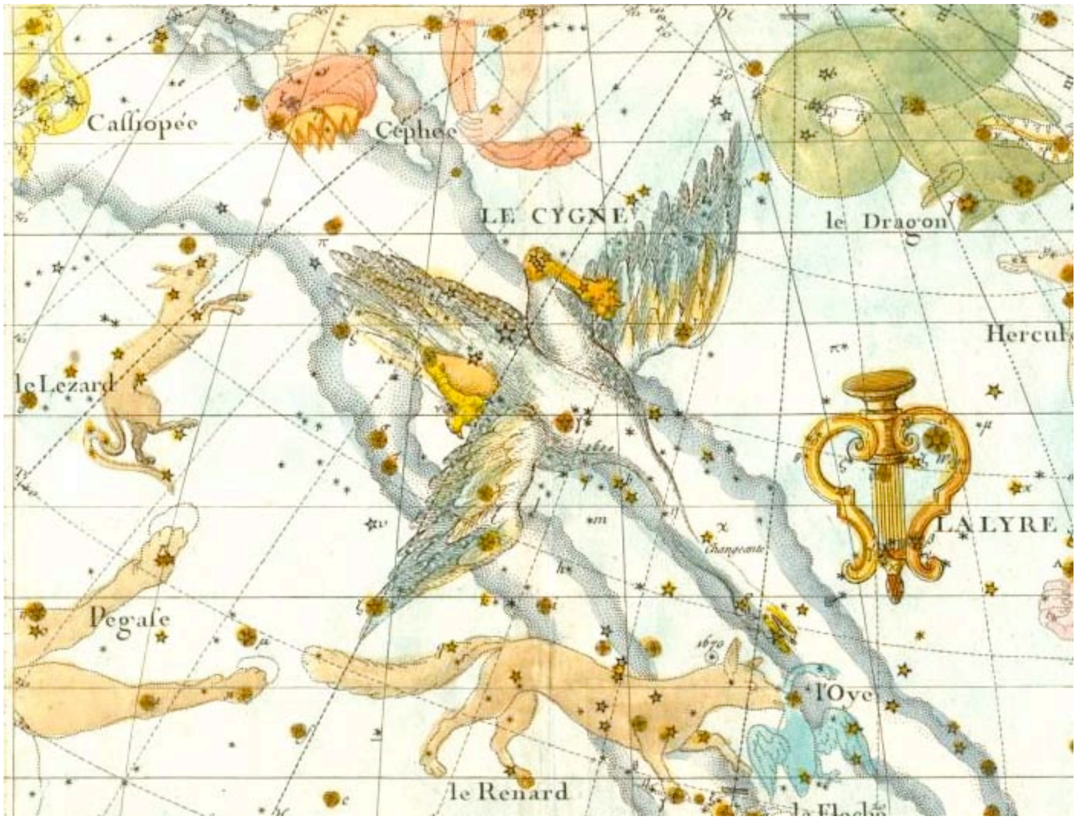
You will be shown a slide of the Big Dipper. After you have become familiar with some of the celestial objects located within this star pattern, you will be able to view it in the night sky with a greater appreciation. Even though Ursa Major is a circumpolar constellation for the Northern Hemisphere, from March through May it is at its highest point in the sky, away from the horizon and light pollution, and easier to observe.

Look at the middle star in the handle of the Big Dipper and you will be able to see the two stars named Mizar and Alcor. Even though they look close together and seem to be touching each other, they are not. They are at different distances from us and just happen to fall in the same line of sight. The term for this apparent closeness from our perspective is *optical double*. During World War I and World War II, these stars were used for testing vision. Anyone who could distinguish the two stars with the unaided eye was given a rating of 20/20. If you look at Mizar and Alcor through a telescope, you will see that Mizar is part of a double star system and has a companion star. So what on casual glance seems to be a single star in this small piece of the sky is in reality three stars.

Within this constellation are several spiral galaxies similar to our own Milky Way, such as M81, M101, and M108. Each one of these galaxies contains billions of stars, and exhibits unique and interesting characteristics. Ursa Major also contains several variable stars. In 1993, an amateur variable star observer from Spain found a bright supernova visible from the Northern Hemisphere. Just think! The information from the death of this star journeyed through space for millions of years before falling through the lens of a telescope into the eye of an observer. Until that moment, no one knew the star had died. Since then, scientists have continued to study this part of the sky to understand more about supernovae.

In Ursa Major, we also encounter M97, a planetary nebula. Contrary to intuition, a planetary nebula has nothing to do with planets. Some stars going through the dying process are not massive enough to explode into supernovae; they just shed some of the outer layers of their atmosphere into clouds of gas that surround them. When viewed through a telescope, the planetary nebula looks like an oval or circular disk with a blue-green central star. M97 is called the “Owl Nebula” because it resembles an owl. The planetary nebula stage represents a brief period in the history of a star. After the nebula dissipates, the highly compressed core will become a white dwarf about the size of the Earth. Our Sun will begin to die in about five billion years; after passing through the red giant stage, it too will become a white dwarf. Perhaps it will throw off a planetary nebula which the inhabitants of some other planet will see, and name after something its shape resembles in their culture.

Investigation 5.4: A Study of the Constellation Cygnus, the Swan



The origin of Cygnus is quite ancient. It has most often been represented as some sort of a bird. In Mesopotamia it was called the Bird of the Forest. It has also been referred to as a duck or a hen. The constellation was named Cygnus by Eratosthenes, a Greek who is famous for calculating the circumference of the Earth by measuring the length of a shadow cast by the Sun on a day when he knew its rays shone directly into the bottom of a well several kilometers away.

One of the myths involved with the swan is the story of Cycnus and his friend Phaethon, the mortal son of the Sun god Helios. Phaethon took the Sun Chariot for a ride and lost control, endangering the gods with his recklessness, and setting fires when the thundering horses came too close to Earth. Jupiter threw Phaethon out of the chariot, and he fell into the river Eridanus and drowned. Cycnus was devastated by his friend's death and dove into the river again and again, collecting the bones of Phaethon so he could bury them. Cycnus did not want his friend to roam as a ghost through the Upperworld for all eternity, but to rest in peace in the Underworld. Jupiter was moved by this devotion and rewarded Cycnus by changing him into a swan, and renaming him Cygnus. Cygnus was placed in the Milky Way, which represents the path of destruction of the Sun Chariot.

Another famous legend is that one day Jupiter saw a beautiful maiden by the name of Leda bathing in the river Eridanus, and changed himself into a swan so he could get close to her without being recognized. When Leda stroked the beautiful swan, Jupiter changed back into his own form.

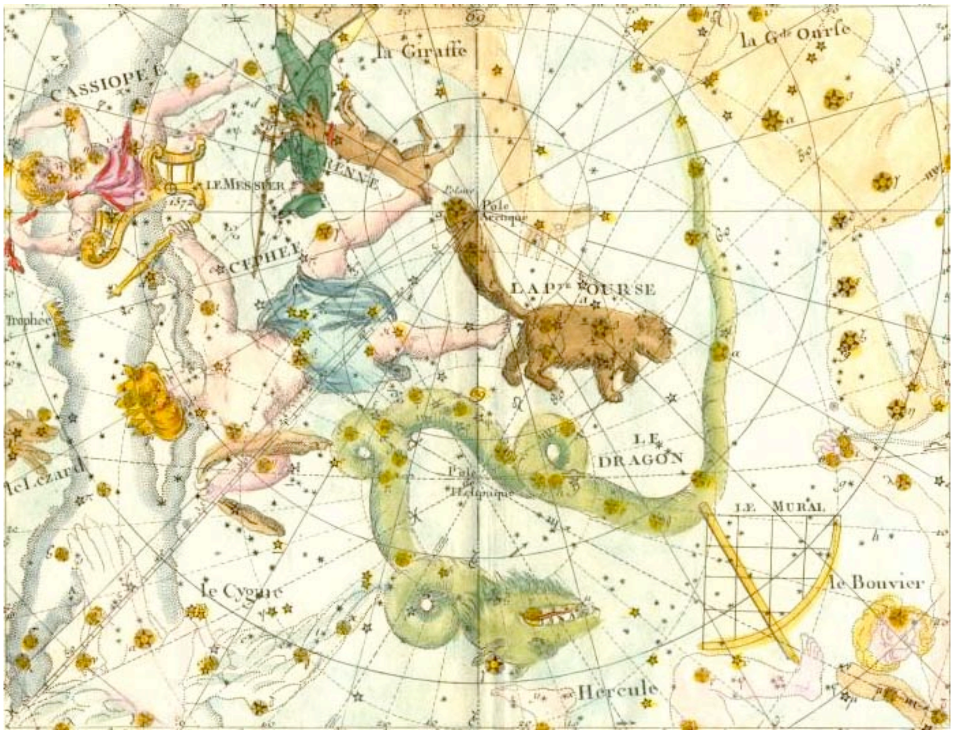
Cygnus is also called the Northern Cross. This name has its origins in the early 1600's. The Northern Cross represents the Cross of Calvary. Many Christians considered it significant that the orientation of the cross on Christmas Eve is upright and prominent on the horizon before it begins its annual descent and disappears from the night sky.

You will be shown a slide of Cygnus, which is visible high in the summer sky. Its brightest star, alpha Cygni, also known as Deneb, is one of the bright stars making up the asterism of the Summer Triangle. Deneb is actually a double star system and is approximately 1500 light-years away. Beta Cygni, or Albireo, is a red supergiant and also part of a binary star system which is easily visible with binoculars or a small telescope. Cygnus lies within the Milky Way and is therefore quite dense with stars. One of its stars, 61 Cygni, was the first star whose distance was measured from Earth using parallax. Parallax is the apparent change in position of a star against the background pattern of stars. You can see this same phenomenon by holding your arm straight out in front of you with your thumb up. Look at your thumb with your left eye closed. Then look at your thumb with your right eye closed. Notice that your thumb appears to "jump" relative to whatever is behind it: this is parallax. This measurement was accomplished in 1837 by Friedrich Wilhelm Bessel, a Prussian astronomer. 61 Cygni is 11 light-years away.

Variable stars abound in this part of the sky. We will study one in particular, W Cygni, which exhibits a large change in magnitude on a regular basis. There are several different types of variable stars. Some that are not very regular are called *semiregular variables*. *Eruptive* or *cataclysmic variables* suddenly change their brightness when either their thermonuclear processes become unstable, or atmospheric material from companion stars fall onto their surface. These semiregular and eruptive stars offer no clue as to when they will brighten. It is fascinating to study these stars, and amateur astronomers play an important role in observing them.

Near the tail of Cygnus is a bright cloud of partially obscured gases called the North American Nebula. The Veil Nebula, the remnant of an ancient supernovae explosion, is also in Cygnus. Cygnus is the home to two open clusters, M29 and M39, and to the Cygnid meteor shower, which seems to emanate from Deneb in July and August.

Investigation 5.5: A Study of Cepheus, the King of Ethiopia

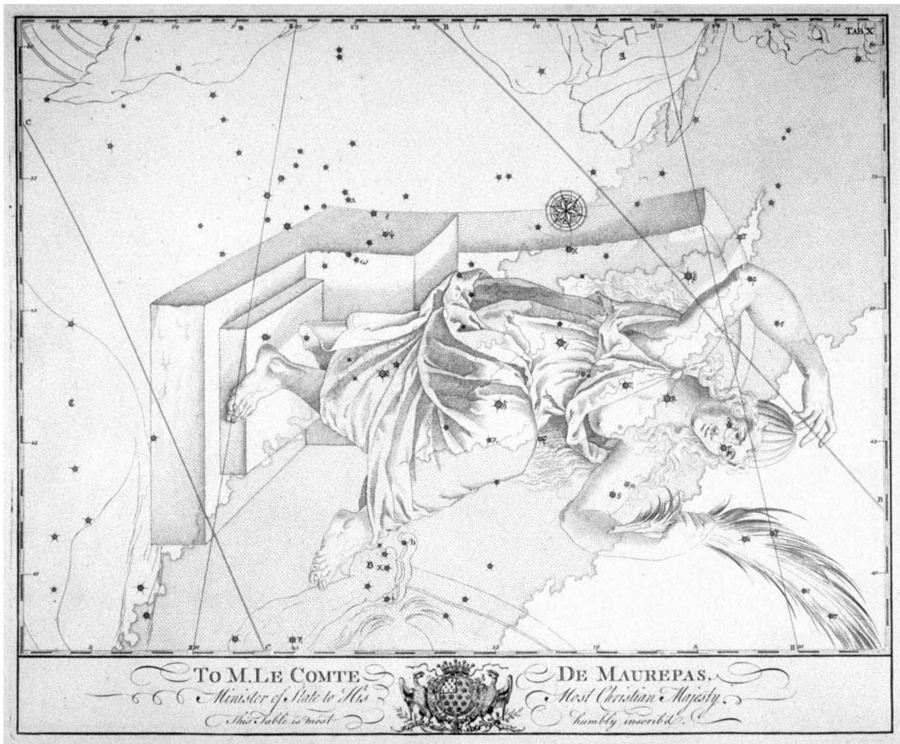


This region of the sky has usually been associated with a king. Arab astronomers called this constellation al-Multafab, the Blazing One, while in China it was called the Secret Throne of the Five Emperors. In Greek mythology Cepheus was an Argonaut and the king of Ethiopia, husband to Cassiopeia. Cepheus and Cassiopeia had a daughter named Andromeda. These three are associated with two other constellations, Perseus and Pegasus the Flying Horse. Because Cassiopeia, vain and boastful, insulted the gods, Cepheus was ordered to sacrifice Andromeda as a punishment. However, Andromeda was saved by Perseus and Pegasus.

Cepheus himself constantly circles the pole, with his feet in the constellation of Ursa Minor, one foot close to Polaris. This is a dark region of the sky, and it is difficult to see any pattern in the stars making up Cepheus that might suggest a king. Not much is known about King Cepheus, and in classical times *all* lands to the south—including India and Arabia—were called Ethiopia, so exactly where his kingdom was located is not known.

Your instructor will show you a slide of Cepheus, a circumpolar constellation in the Northern Hemisphere and most easily visible in the summer and fall. The variable star delta Cephei is one of the most interesting objects in this constellation. It is visible with the unaided eye and its period of change in brightness is only a few days. This is one of the first stars that new variable star observers study. You will also learn how to locate this variable star, record and analyze the data, and learn why this star and others of this type show variability. Delta Cephei is the prototype of all Cepheid variables, which are used by astrophysicists in determining the distance to stars and the age of the universe.

Investigation 5.6: A Study of the Constellation Cassiopeia, the Queen of Ethiopia



Cassiopeia's vanity about her beauty angered Poseidon, who unleashed the monster Cetus and demanded the sacrifice of her daughter, Andromeda. As an eternal reminder that mere mortals should not compare themselves to the gods, Cassiopeia travels constantly around the North Celestial Pole. When she is above the North Pole, the constellation has the shape of an M; when below the North Pole the M turns upside down into a W shape. During this time Cassiopeia is decidedly in danger of falling off her throne and must hang on to avoid falling out of the sky. Because the gods sometimes show temperance in their anger, for part of the year Cassiopeia is allowed to sit upright and temporarily regain her dignity. Cassiopeia, Cepheus, and Andromeda are often portrayed as being dark-skinned, since they were said to come from Ethiopia.

The five stars that make up the W shape were seen as the fingertips of a hand by the ancient Arabs, and was referred to as Tinted Hand, Dyed Hand, or Broad Hand Dyed with Henna. Arab women sometimes dyed their nails, hands, and feet with henna at weddings and ceremonies, and sometimes as protection from the heat. After the arrival of Muhammad, the Tinted Hand became the hand of Fatima, daughter of Muhammad, covered in blood. The Arabs have also called this constellation the Lady on the Throne.

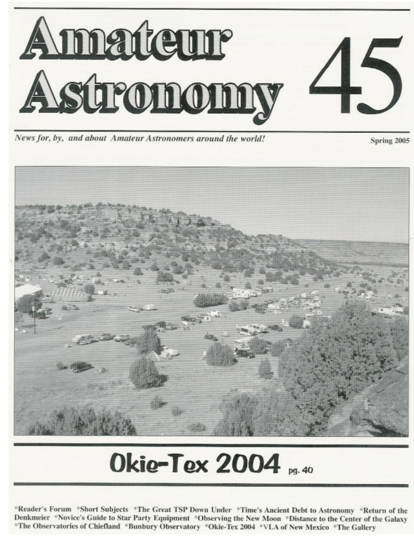
Some minor myths in this part of the world see a camel which incorporates both Cepheus and Cassiopeia, and sometimes Perseus.

Chinese mythology associates this constellation with a chariot, the transportation used by those visiting the court of the emperor. It is also associated with two great charioteers, Wang-liang and Tsaou-fou. To natives of the Marshall Islands, a huge porpoise lives in this part of the sky which incorporates four constellations, including Cassiopeia, which is the tail of the porpoise. Siberians see five reindeer, and Laplanders see the antlers of a moose.

You will be shown a slide of the constellation Cassiopeia. It is circumpolar in the Northern Hemisphere, and in the fall it is high in the sky and least affected by light pollution. Part of this constellation lies within the Milky Way.

Cassiopeia has its own share of bright open clusters, including M52 and M103, as well as a planetary nebula called the Bubble Nebula. It also includes a large number of various types of variable stars.

Astronomy is for Everybody


Amateur Astronomy 45

News for, by, and about Amateur Astronomers around the world! Spring 2005

Okie-Tex 2004 pg. 40

*Reader's Forum *Short Subjects *The Great TSP Down Under *Time's Ancient Debt to Astronomy *Return of the Denkmeier *Novice's Guide to Star Party Equipment *Observing the New Moon *Distance to the Center of the Galaxy *The Observatories of Chiefland *Bunbury Observatory *Okie-Tex 2004 *VLA of New Mexico *The Gallery

The stars are free. Anyone can look up at the night sky and see the stars. And with a little knowledge, practice, and skill, anyone can begin to understand what is happening out there. People have been doing this for thousands of years. Some of the most important discoveries about the stars and planets were made by individuals who began by looking up and wondering.

But the individual's observations cannot be of much use if they are made in isolation. To look up and wonder about the stars and not talk about these questions with others is like someone writing wonderful poems and putting them away in a desk drawer. What we see and think about is just the beginning: our observations will mean something if we can make them known to others who have a similar interest in the stars. This works in both directions: something may be happening in the stars that you yourself have not seen, but you learn about it because others have seen the event and have communicated it to you.

There are amateur astronomy groups everywhere in the world. This happens anywhere two or more people get together to talk about what they see in the stars and how they go about it. An astronomy group can be two, or a few, or dozens, hundreds, or thousands of people who are eager to share what they know with others.

Professional astronomers have come to depend on these formal and informal networks of amateur astronomers' clubs and organizations. Most unpredictable events-like the appearance of novae and supernovae, comets, meteor and meteorite events, and sudden brightening or fading of stars-would go unnoticed by the professional astronomer if it were not for the nightly observations communicated by amateurs to their astronomy groups.

The Story of the AAVSO

...and it is a fact that only by the observation of variable stars can the amateur turn his modest equipment to practical use, and further to any great extent the pursuit of knowledge in its application to the noblest of the sciences.

- William Tyler Olcott, 1911, Co-Founder of the AAVSO

In 1909, William Tyler Olcott, a lawyer, amateur astronomer, and the author of *The Field Book of the Stars* and other popular astronomy books, heard Harvard College Observatory Director Edward C. Pickering give a talk and exhibit some light curves and charts of variable stars. This fascinated Olcott, who immediately afterwards wrote Pickering to ask if he could become a variable star observer. In response, Harvard assistant and variable star observer Leon Campbell went to Norwich, Connecticut, where Olcott lived, "to initiate Mr. Olcott in the art of variable star observing." On February 2, 1910, Olcott "succeeded in locating the field of Omicron Ceti" and made his first official variable star observation. From that date on, Olcott regularly sent observations The AAVSO annual meeting, 1917. to Professor Pickering at the Harvard College Observatory.

The March 1911 issue of *Popular Astronomy* carried an article by Olcott entitled, "Variable Star Work for the Amateur with Small Telescopes." Events then moved quickly and in the November issue, Olcott, signing himself "Corresponding Sec'y," announced that an organization had been formed by co-founder E.C. Pickering and himself, W.T. Olcott, and he suggested as its name, The American Association of

Variable Star Observers (AAVSO). He listed six people who had indicated their desire to cooperate, and included a list of 71 stars he himself had been observing. Thus, with the founding of the AAVSO, Pickering's dream of advocating variable star observations by amateurs became a reality.

The AAVSO annual meeting, 1917.

By the end of its first year, over 6000 observations of 175 stars from 19 observers were published in *Popular Astronomy*. As participation increased, Olcott wanted to become better acquainted with the observers; he wrote, "I wanted to see what they look like." On April 8, 1914, the first informal meeting was arranged in a restaurant on 42nd Street in New York.

In November 1915, the first official meeting of the AAVSO took place at Harvard College Observatory, and the twelve observers who attended met co-founder Edward Pickering and Leon Campbell, the first recorder.

At its meeting in November 1917, the group decided to be organized formally and in October 1918, the AAVSO was incorporated under the laws of the Commonwealth of Massachusetts.

The organization grew steadily in membership. By 1950, observers were contributing data at a rate of about 55,000 variable star observations each year. In 1957, with the launching of the Russian satellite *Sputnik*, the activities of the Association also took off. AAVSO's first involvement with space research took place with participation in satellite tracking. The involvement of observers in professional research increased. The International Astronomical Union, at its General Assembly in 1961, suggested that the AAVSO become the central repository for all variable star observations.

In 1962, the two-millionth observation was received from Leslie C. Peltier, only 16 years after the one-millionth in 1946. Increasing numbers of requests came from professional astronomers for AAVSO data as special interest in flare stars, eclipsing binaries, cataclysmic and nebular variables, and extragalactic supernovae accelerated, and observations of variable stars expanded beyond the optical region of the electromagnetic spectrum with instruments aboard balloons and planes.

The participation of AAVSO observers was sought by space researchers in almost all of the satellite and ground-based observing runs on cataclysmic variables. AAVSO's collaboration through observers' closely monitoring target stars and alerting astronomers to observed activity played an important role in the success of these sophisticated observing programs. Requests from astronomers for AAVSO data increased exponentially during the 1970s and 1980s, and the vital contributions of AAVSO observers were acknowledged in numerous astronomical papers.

Today the AAVSO stands strong on the foundation built by such giants as William Tyler Olcott, Edward C. Pickering, Leon Campbell, and the thousands of dedicated members and observers. The Association is international in scope with its 1300 members worldwide, and, with over 15 million observations, has the largest data bank on variable stars in the world. The AAVSO is rightly a source of pride to all who have contributed to what it is today.

The AAVSO annual meeting, 1996.

SPACE TALK

Variable stars—stars that change in brightness—are divided into two major groups, **extrinsic** and **intrinsic**. Extrinsic variables change in brightness either by the eclipse of one star by another, or by the effects of stellar rotation. An **eclipsing binary** system is created when two stars are orbiting each other and one star, from our perspective on Earth, happens to pass in front of and then behind the other star. These magnitude changes result in a distinct pattern that is observable. One example of an eclipsing binary is beta Persei (Algol).

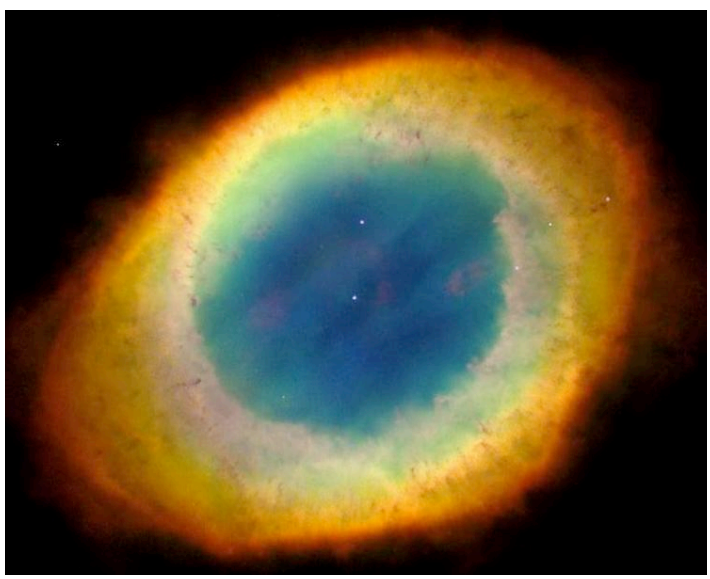
Our own Sun is also a type of extrinsic variable star! Our Sun has sunspots, which are related to its magnetic activity. Sometimes there is a large area of dark sunspots on the Sun's surface, and as the Sun rotates, the sunspots rotate also—sometimes facing the Earth, sometimes facing away from the Earth. The Sun's apparent magnitude increases when the sunspots face away from the Earth, and decreases when the sunspots face towards the Earth. Other stars also have "starspots" that produce changes in magnitude as they rotate.

Intrinsic variable stars change in magnitude due to internal physical changes that cause them to periodically brighten and fade. **Pulsating variables** are one type of intrinsic variable star. Stars are luminous balls of gas held in equilibrium by two forces operating in opposing directions—gravitational force directed towards the center of mass of the star, and **radiation pressure** from the thermonuclear fusion process directed from the core towards the surface of the star. Some stars pulsate because a small imbalance between these two forces stops the star from reaching equilibrium. When the star pulsates, it expands past its equilibrium point until the expansion is slowed and reversed by the force of gravity, and it then contracts. It then overshoots its equilibrium point again until the contraction is slowed and reversed by the increased radiation pressure from the core of the star. The mechanism responsible for the continued pulsations or oscillations of most variable stars does not originate in the core, but in regions of instability within the stellar atmosphere. Delta Cephei, in the constellation Cepheus, belongs to one type of pulsating variable called Cepheid variables.

Another group of intrinsic variable stars are **eruptive variables**. There are several types of eruptive variables which undergo eruptions or explosions instead of pulsations. The most spectacular are the catastrophic **supernovae** explosions which occur in massive dying stars. The thermonuclear fusion process in stellar cores consists of the conversion of hydrogen to helium. When the supply of hydrogen is exhausted, the nuclear fires start to sputter and the star begins to collapse. The resulting stages of **stellar evolution** for dying stars depends upon their initial mass. When stars twice as massive as our Sun begin to die, heavier and heavier elements are produced by the fusion process. Eventually, in the most massive stars, the nuclear fires burn so hot during the final stages of collapse that iron starts to fuse. All elements lighter than iron produce energy during the fusion process, but iron consumes energy. When iron starts to fuse, the stage is set for complete disaster—nothing can stop the total destruction of the star. In a fraction of a second, a star that has existed for millions of years will cease to exist in the visible universe. The unimaginably violent death leaves behind nebulae—beautiful layers of atmospheric material thrown from the surface during the explosion—sometimes the only evidence of the star's previous existence. Supernovae display light increases of 20 magnitudes or more and can outshine all other stars in a galaxy.

Betelgeuse (alpha Orionis) is a luminous red **supergiant** in the constellation Orion. It is a **semiregular variable** star, having periods of regular pulsations interrupted by periods of irregular light variation. Betelgeuse is five times more massive than the Sun and is in a **binary system** with a 14th-magnitude companion star. Betelgeuse is 410 light-years away, and will eventually become a supernova. Here on Earth, we will not know of the destruction of Betelgeuse until 410 years after its core has evolved into a neutron star, leaving its atmospheric layers behind. Betelgeuse does not have enough mass to become a black hole.

Another example of eruptive variables are **novae**. Novae result from stars in two different evolutionary stages orbiting each other in close binary systems. For example, a star with its atmosphere bloated during the **red giant** stage may be orbiting a dense, hot **white dwarf**. The loosely-held outer atmospheres of a red giant sometimes whirl into a disk and spiral onto the surface of the more dense white dwarf, triggering nuclear reactions on the surface. The increase in brightness can range from 5 to 20 magnitudes. A white dwarf has an extremely dense carbon core, the end result of stellar evolution for low-mass stars like the Sun. Before the final collapse into the white dwarf stage, these stars go through a red giant phase, during which a **planetary nebula** is sometimes ejected from the star. The ejection of a planetary nebula is not as violent as a supernova explosion, and after approximately 50,000 years planetary nebulae become too thin and tenuous to be seen. In approximately 5 billion years, the Sun will evolve through a red giant phase and its bloated surface will extend beyond the orbit of Mars, incinerating the inner planets. It may eject a planetary nebula before settling down as a white dwarf, slowly radiating its heat energy into space. Eventually, with all its heat dissipated, the Sun will become a **black dwarf**, a cold dense chunk of carbon, still accompanied by its frozen planetary family.



M57, the Ring Nebula in the Constellation of Lyra (HSTsI)