Variable Star Classification and Light Curves

An AAVSO course for the

Carolyn Hurless Online Institute for
Continuing Education in Astronomy (CHOICE)

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Course Description and Requirements for Completion

This course is an overview of the types of variable stars most commonly observed by AAVSO observers. We discuss the physical processes behind what makes each type variable and how this is demonstrated in their light curves. Variable star names and nomenclature are placed in a historical context to aid in understanding today's classification scheme.

This class will last four weeks. There are four chapters, so we will progress rapidly through one chapter per week, more or less. There will be topics for discussion regarding each chapter and a quiz or exercise each week on Friday.

The discussion topics will be fun as well as enlightening. Often there will not be a right or wrong answer. The questions will be designed to make you think and look at variable star classification in a critical or unconventional manner.

You will also be asked to do a paper review of a journal article on some variable star classification or light curve related subject. You will share this with the class as a brief description of the paper and its main points in the discussion forum. Papers can be selected from arXiv or any astronomical journal you can access freely. You may also want to select a paper from the AAVSO in Print section of the AAVSO website, and tell us how AAVSO data was used to further the research presented.

At the end of the course you will either pass or fail. There are no grades. Those that pass will be awarded a certificate of completion and your AAVSO website profile and your membership records in our DB will reflect that you are a graduate of the course.

In order to pass this course you must successfully complete all the quizzes, exercises and participate in the online forum discussions. You cannot pass if you do not participate in the discussions.

One or more of you may also be asked to be the instructor for the next cohort of students taking this course. Those that act as teachers will be given free admission to another CHOICE course of their choosing in the future.

Chapter One - Introduction

What are variable stars?

When we look at the night sky we see stars twinkling overhead, joined in familiar patterns that have remained the same for thousands of years. The Sun, Moon and planets perform their celestial dance across the sky against a fixed background of stars. To the casual observer, these stars seem perfect, steady, peaceful, serene, and unchanging.

Nothing could be further from the truth. The universe we know today is a violent and dangerous place, with dark clouds of dust and gas so cold atoms almost cease to move and explosions so extreme that entire star systems are wiped out in the blink of an eye. Stars fuel most of the restless insanity of our universe.

So, what is a star? Stripped to its simplest components, a star is a giant ball of gas that is performing a delicate balancing act between the force of gravity trying to crush all the mass into a smaller ball in the center of the star and the force of nuclear burning at the core of the star trying to blow it apart. As the star evolves throughout its lifetime, there are sometimes battles fought between these two forces that ebb and flow, swelling and shrinking the star. If one or the other of these forces finally wins the battle, the star loses its life, either being crushed out of existence into a black hole, or exploding into space as a supernova.

These are only a few of the reasons a star may vary or appear to vary from our station on Earth. There are many more, as you are about to learn. Every star has been and will be variable in its light output at one time or another. It is inevitable. If you could just live long enough you'd see every star is a variable star.

Indeed, we can tell a lot about stars by their variability, like how far away, how old, how massive, or how large or small. This is precisely why variable stars are so important to the study of our universe. To understand variable stars is to understand the secret lives of stars.

Stars are the building blocks of the larger structures in our universe. They form pairs and clusters, and aggregate by the billions to form galaxies, which then form even larger groups and structures. They also play an important role on smaller scales, playing host to planets, asteroids and comets. On a molecular scale, stars are the material factories of the universe. They make the stuff our Earth and you and I are composed of. Where ever there is life in the universe you can be sure there will be a star not too far away, supplying the raw materials and energy needed for life to exist.

To know our place in the cosmos you have to understand stars. To know the stars you must understand their variability.

The first known variable stars

Ancient peoples were much more in tune with the night sky than we are today. Probably because, unimpeded by our current day light pollution, they could actually see the stars from their homes at night, and let's face it, they didn't have television or the Internet to distract them!

They used the Sun, Moon and stars to tell time, plant and harvest crops, prepare for winter, celebrate spring, and to predict floods and annual migrations of animals they hunted for survival.

They were well aware of the motion of the planets among the background stars, solar and lunar eclipses, the flashes of meteors and the occasional visit of a bright comet, but to most societies, for thousands of years, the stars were considered to be fixed and unchanging. In fact, it was actually ingrained in some cultures philosophies that the stars were "perfect" and therefore could not change.

Oriental cultures were not so restricted, and records exist today of their observations of supernovae, novae, great comets and eclipses. Among these are some 80 'new stars' before 1600 A.D. Although other cultures my have noted some of them, these are the best surviving records we have of these events. We know these today as supernovae and novae, variable stars in the extreme.

The sixteenth century not only brought enlightenment and a renaissance to the West, but coincidentally, two supernovae in our galaxy within about thirty years. The first erupted in November 1572 and was nearly as bright as the planet Venus! Tycho Brahe not only established its position to a high degree of precision, but he placed it at a distance among the stars. This was indeed a 'new star', not an atmospheric phenomena or a planetary interloper. He also recorded its decreasing brightness in relation to planets and other bright stars to a high degree of precision.

In 1596, David Fabricius discovered omicron Ceti, now known as Mira, and in 1638 Johannes Holwarda determined it was a periodic variable, brightening and dimming in approximately 11 months. Mira was probably the first known case.

Tycho's supernova was followed in 1604 by another 'new star' whose fixed position among the stars was established by Johannes Kepler. Kepler's star was as bright as Jupiter, and also the last supernova to be seen in our galaxy since then. We are long overdue for another spectacular display of a galactic supernova event.

Once Galileo turned his telescope to the heavens the floodgates to astronomical knowledge were swung open, but it still took a hundred years for variable stars to begin to take their place in the studies of astronomers.

William Herschel discovered the variability of alpha Herculis and 44i Bootis in the 1700's. Later that century, two English gentlemen, John Goodricke and Edward Pigott, made a special point of studying variable stars. Pigott discovered eta Aquilae, R Corona Borealis and R Scuti, while Goodricke discovered the variability of delta Cephei and beta Persei (Algol). Together they proposed the theory that Algol's variability might be caused by eclipses of the star by a planetary companion, an astounding insight that was very close to the truth!

By the middle of the nineteenth century there were some 18 known variable stars and another several dozen suspected variables. The organized study and recording of observations led to the establishment of the Variable Star Section of the British Astronomical Association (BAAVSS) in 1890, followed soon after by the establishment of variable star studies at Harvard College Observatory which eventually led to the founding of the American Association of Variable Star Observers (AAVSO) in 1911.

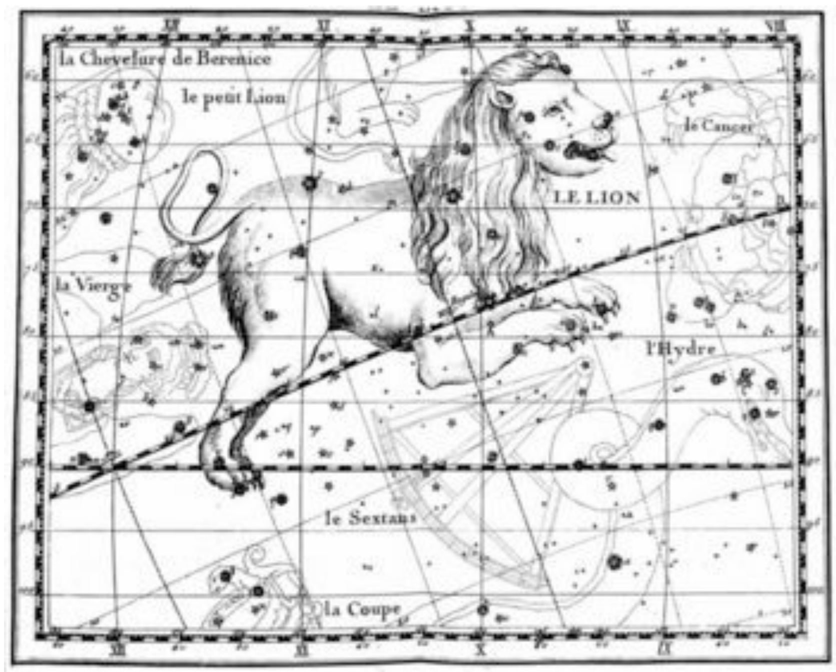
There are now hundreds of thousands of known variable stars, and more are being discovered all the time. Sorting out the names and taxonomy of the variable star zoo is the object of this course.

Constellation Names

Traditional variable star names are a combination of a letter and/or number combination prefix and a constellation name in genitive (possessive) form, such as R Leonis, or V849 Herculis. So it is useful to understand constellation names and their origins and usage.

Today there are 88 constellations officially recognized by the International Astronomical Union (IAU), the body responsible for naming the stars, planets, moons, comets and variable stars. But that is a recent development. People have been assigning names to stars, groups of stars, and constellations for over 6,000 years, and frankly, it's been somewhat of a free-for-all! Until the twentieth century, celestial mapmakers were free to make up constellations and boundaries based on whatever people, animals, or mythical beasts they could dream up.

Ancient astronomers and cultures had names for the groupings of stars along the ecliptic, because this was the path through which the Sun, Moon and known planets of the time traveled, and they assigned magical and future predicting qualities to these cyclical motions. Hardly any of the very ancient constellation names survive to today. It wasn't until 150 B.C. that Claudius Ptolemy published the *Almagest,* his famous treatise on mathematics and astronomy that constellation names we recognize today were formalized in writing. Of the 48 original star patterns he described, only two, the Pleiades and Argo Navis, are no longer recognized as constellations.



A star map of Leo the Lion, one of the few constellations that actually looks like its namesake to modern observers.

In the 1500's navigators exploring the southern hemisphere began naming southern constellations. Italian navigator, Amerigo Vespucci, was the first to describe the Southern Cross, Crux, and Triangulum Australe. Dutch navigators Frederick de Houtman and Pieter Dirksz Keyser created Apus, Chamaeleon, Dorado, Grus, Hydrus, Indus, Musca, Phoenix, Tucana and Volans.

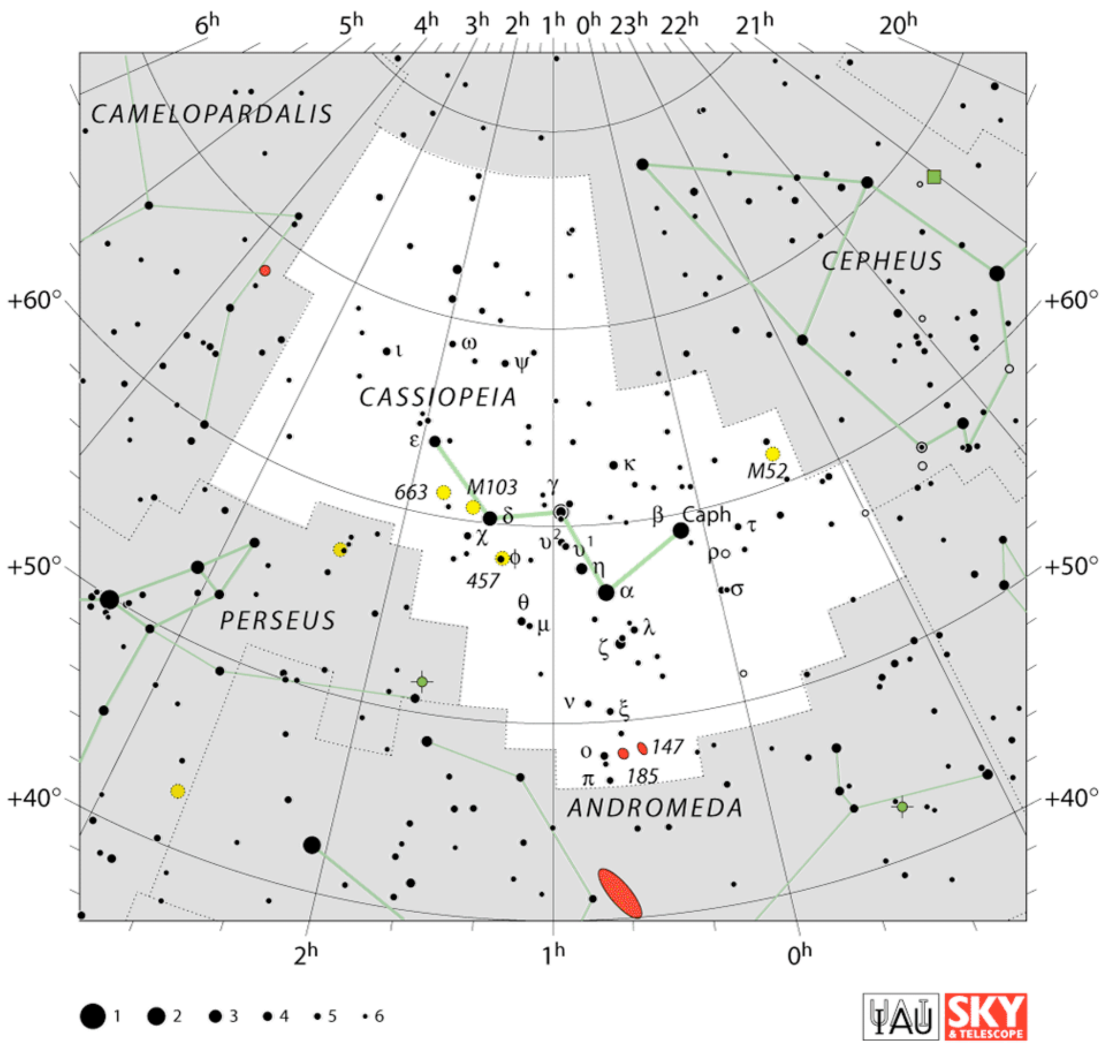
Sixteenth century mapmakers, Gerard Mercator and Petrus Flemish created the new constellations of Coma Berenices and Columba, respectively. In 1690, German astronomer, Johannes Hevelius documented Canes Venatici, Lacerta, Leo Minor, Lynx, Scutum, Sextans and Vulpecula in his atlas of the heavens.

Not to be outdone, in 1756 the French astronomer Nicolas Louis De Lacaille invented 14 new constellations representing scientific equipment of the day: Antlia, Caelum, Circinus, Fornax, Horologium, Mensa, Microscopium, Norma, Octans, Pictor, Pyxis, Reticulum, Sculptor and Telescopium. And in 1764, French mapmaker, Gilles Robert de Vaugondy divided up Ptolemy's Argo Navis into Carina, Puppis and Vela.

In an effort to bring order to the madness, American astronomer Henry Norris Russell proposed a system of three letter abbreviations for the constellations at the First General Assembly of the IAU in 1922, and by 1928 the IAU had set official boundaries for the 88 constellations we recognize today.

This process did leave a few orphan stars in its wake. The variable star T Leo no longer resides in the constellation of Leo and was renamed QZ Virginis, and the 4th magnitude star 10 Ursae Majoris now is part of the constellation Lynx.

The IAU maintains an excellent page that lists the 88 constellations, their abbreviations and pronunciations, and includes star maps with the borders of each well defined. You can visit it here: http://www.iau.org/public/constellations/



The IAU/Sky and Telescope constellation map of Cassiopeia

Greek Letter Names (Bayer Designations)

A Bayer designation is a stellar designation in which a specific star is identified by a Greek letter, followed by the genitive form of its parent constellation's Latin name. The original list of Bayer designations contained 1,564 stars.

Most of the brighter stars were assigned their first systematic names by the German astronomer Johann Bayer in 1603, in his star atlas Uranometria. Bayer assigned a lower-case Greek letter, such as alpha (α), beta (β), gamma (γ), etc., to each star he catalogued, combined with the Latin name of the star's parent constellation in genitive (possessive) form. For example, Aldebaran is designated α Tauri (alpha Tauri), which means "alpha of the Bull".

A single constellation may contain fifty or more stars, but the Greek alphabet has only twenty-four letters. When these ran out, Bayer began using lower-case Latin letters: hence s Carinae and d Centauri. Within constellations having an extremely large number of stars, Bayer eventually advanced to upper case Latin letters, as in G Scorpii and N Velorum. The last upper-case letter used by Bayer was Q.

As luck would have it, many of these bright stars turned out to be variable stars, so they are often known by their Bayer designations. Examples are alpha Orionis, beta Lyrae, delta Cephei and eta Aquilae.

Variable Star Names

Argelander's System for Naming Variable Stars

Generally regarded as the father of variable star science, Frederich W. A. Argelander invented the traditional system used to name variable stars today. Under this system, variable stars are named using a variation on the Bayer designation format, combining an identifying label with the Latin genitive (possessive) of the name of the constellation in which the star resides. He started with the letter R to avoid confusion with the Bayer designated stars. As each new variable in a constellation was discovered it received the next letter combination in line.

The rules for naming stars in order of their discovery is this:

- Stars with existing Greek letter Bayer designations are not given new designations.
- Otherwise, start with the letter R and go through Z.
- Continue with RR through RZ, and then use SS through SZ, TT through TZ and so on until ZZ.
- Then it reverts to the beginning of the alphabet, AA through AZ, BB through BZ, CC through CZ and so on until reaching QZ, omitting J in both the first and second positions.

- Note that the first letter is never further up the alphabet than the second, that is to say no star can be BA, CA, CB, DA or so on.
- The Latin script is abandoned after 334 combinations of letters and numbers are used, starting with V335, V336, and so on.

It seems like a cumbersome way to name things, but you must realize that in Argelander's time stellar variability was considered to be a rare phenomenon. I doubt they thought they would ever run out of letter combinations. Astronomers of the day would be shocked to learn that we now have names like V2346 Cyg and V5558 Sgr.

Other Naming Conventions

As if that weren't confusing enough, there are now a host of other prefixes and numbers assigned to variable stars and objects. The following is a guide to help you understand what these names mean and where they came from.

NSV xxxxx - These are stars in the Catalog of New and Suspected Variable Stars, produced as a companion to the Moscow General Catalog of Variable Stars (GCVS) by B.V. Kukarkin et al. All stars in the NSV have reported but unconfirmed variability, in particular, lacking complete light curves. Some NSV stars will eventually prove truly variable; others will be spurious. Information about this and the General Catalog of Variable Stars can be found at: http://www.sai.msu.su/groups/cluster/gcvs/gcvs/intro.htm

VSX Jhhmmss.s+ddmmss- This is the system used by the International Variable Star Index (VSX), maintained by the AAVSO. These J2000 coordinate designations are applied to newly cataloged objects in VSX. http://www.aavso.org/vsx/

Many stars and variable objects are assigned prefixes based on astronomer, survey or project names. Many are temporary designations until they are assigned a conventional name in the GCVS.

3C xxx - These are objects from the Third Cambridge (3C) catalog (Edge et al. 1959), based on radio-wavelength observations at 158 MHz. There are 471 3C sources, numbered sequentially by right ascension. All 3C sources are north of -22 declination. The 3C objects of interest to variable star observers are all active galaxies (quasars, BL Lacs, etc.).

Antipin xx- Variable stars discovered by Sergej V. Antipin, a junior researcher working for the General Catalogue of Variable Stars Group.

HadVxxx - This represents variables discovered by Katsumi Haseda. Haseda's most recent discovery was Nova 2002 in Ophiuchus, V2540 Oph.

LD xxx - Variables discovered by Lennart Dahlmark, a Swedish retiree living in southern France are given this prefix. Dahlmark has been conducting a photographic search for new variable stars; discovering several hundred to date.

He-3 xxxx - Variables from Henize, K. G. 1976, "Observations of Southern Emission-Line Stars", Ap.J. Suppl. 30, 491.

HVxxxxx - Preliminary designations of variables discovered at Harvard Observatory.

Lanning xx - Discoveries of UV-bright stellar objects by H. H. Lanning from Schmidt plates centered primarily on the galactic plane. In all, seven papers entitled "A finding list of faint UV-bright stars in the galactic plane" were published.

Markarian xxxx - The widely used abbreviation for Markarian objects is Mrk. These are active galaxies from lists published by the Soviet Armenian astrophysicist B.E. Markarian. Markarian looked for galaxies that emit unusually strong UV radiation, which comes from either pervasive star-formation HII regions or from active nuclei. In 1966, Markarian published 'Galaxies With UV Continua'. Around that time, he started the First Byurakan Spectral Sky Survey (FBS), which is now completed. In 1975, Markarian initiated a Second Byurkan Survey (SBS). His collaborators continued the SBS after his death. For more information see 'Active Galactic Nuclei', by Don Osterbrock.

MisVxxxx - The stars are named MisV after MISAO Project Variable stars. The MISAO Project makes use of images taken from all over the world, searching for and tracking astronomically remarkable objects. The number of variables discovered so far reached 1171 on May 15, 2002. Few of these stars have light curves, and the type and range of many are still undetermined. The project website URL is: http://www.aerith.net/misao/

S xxxxx - These are preliminary designations of variables discovered at Sonneberg Observatory.

SVS xxx - Soviet Variable Stars, indicates preliminary designations of Soviet-discovered variables.

TKx - TK stands for T.V. Kryachko. The TK numbers of new variables continue a numbering system first introduced in Kryachko and Solovyov (1996). The authors invented this acronym.

Another group of objects is labeled with the prefix O, then a letter, then a number (OJ 287 for example). These objects were detected by the Ohio State University radio telescope "Big Ear" in a series of surveys known as the Ohio Surveys.

Many variables are named with prefixes associated with surveys or satellites, combined with the coordinates of the object.

2QZ Jhhmmss.s-ddmmss - Objects discovered by the 2dF QSO Redshift Survey. The aim is to obtain spectra of QSOs out to redshifts so high the visible light emitted by these objects has shifted into the far infrared. The observations are actually of the ultra-violet part of the spectrum that has been redshifted into the visible. As with most QSO surveys,

a serendipitous byproduct is the discovery of CVs and other blue stars. A description and awesome pictures of the equipment can be found here:
http://www.2dfquasar.org/Spec_Cat/basic.html
Home site: http://www.2dfquasar.org/index.html

ASAS hhmmss+ddmm.m - This is the acronym for All Sky Automated Survey, which is an ongoing survey monitoring millions of stars down to magnitude 14. The survey cameras are located at the Las Campanas Observatory in Chile, so it covers the southern sky from the pole to about +28 degrees declination.

FBS hhmm+dd.d - Stands for First Byurakan Survey and the coordinates of the object. The First Byurakan Survey (FBS), also known as the Markarian survey, covers about 17,000 square degrees.

EUVE Jhhmm+ddmm - These are objects detected by NASA's Extreme Ultraviolet Explorer, a satellite dedicated to studying objects in far ultraviolet wavelengths. The first part of the mission was dedicated to an all-sky survey using the imaging instruments that cataloged 801 objects. Phase two involved pointed observations, mainly with the spectroscopic instruments. One of the highlights of the mission was the detection of Quasi Periodic Oscillations (QPOs) in SS Cyg.

FSVS Jhhmm+ddmm - Discoveries from the Faint Sky Variability Survey, the first deep wide field, multi-color, time-sampled CCD photometry survey. It was specifically aimed at detecting point sources as faint as 25th magnitude in V and I and 24.2 in B. Targets were faint CVs, other interacting binaries, brown dwarfs and low mass stars and Kuiper Belt Objects.

HS hhmm+ddmm- The Hamburg Quasar Survey is a wide-angle objective prism survey searching for quasars in the northern sky, avoiding the Milky Way. The limiting magnitude is approximately 17.5B. The taking of the plates was completed in 1997.

PG hhmm+DDd- Palomar Green Survey conducted to search for blue objects covering 10714 square degrees from 266 fields taken on the Palomar 18-inch Schmidt telescope. Limiting magnitudes vary from field to field, ranging from 15.49 to 16.67. The blue objects detected tend to be quasars and cataclysmic variables. The CVs were documented in Green, R. F., et al. 1986, "Cataclysmic Variable Candidates from the Palomar Green Survey", Ap. J. Suppl. 61, 305.

PKS hhmm+ddd - This was an extensive radio survey (Ekers 1969) of the southern sky undertaken at Parkes (PKS), Australia, originally at 408 MHz and later at 1410 MHz and 2650 MHz. These sources are designated by their truncated 1950 position. For example 3C 273 = PKS 1226+023. This is still the most common, and useful, system of naming quasars.

ROTSE1 thru 3 Jhhmmss.ss+ddmmss.s - The Robotic Optical Transient Search Experiment (ROTSE) is dedicated to the observation and detection of optical transients on time scales of seconds to days. The emphasis is on gamma-ray bursts (GRBs). Objects detected by this survey are designated with positions to 0".1 precision.

ROSAT is an acronym for the ROentgen SATellite. ROSAT was an X-ray observatory developed through a cooperative program between Germany, the United States, and the United Kingdom. The satellite was designed and operated by Germany, and was launched by the United States on June 1, 1990. It was turned off on February 12, 1999.

Prefixes for x-ray sources detected by ROSAT include, 1RXS, RXS and RX. The J2000 coordinates for the source are then stated according to the accuracy of the X-ray position and the density of stars in the field.

arcsecond accuracy ---> RX J012345.6-765432
tenth-arcmin accuracy ---> RX J012345-7654.6
arcmin accuracy ---> RX J0123.7-7654

Distressingly, these can all refer to a single object!

Rosino xxx or N xx - Variables discovered by Italian astronomer L. Rosino, primarily in clusters and galaxies through photographic surveys.

SBS hhmm+dd.d - Indicates objects discovered by the Second Byurakan Sky Survey, plus the coordinates of the object.

SDSSp Jhhmmss.ss+ddmmss.s - These are discoveries from the Sloan Digital Sky Survey. The positions of the objects are given in the names. SDSS- (Sloan Digital Sky Survey), p- (preliminary astrometry), Jhhmmss.ss+ddmmss.s (the equinox J2000 coordinates). In subsequent papers on CVs detected by SDSS (Szkody et al) the p was dropped and the names became simply SDSS Jhhmmss.ss+ddmmss.s.

TAV hhmm+dd - The Astronomer Magazine, in England, has a program that monitors variable stars and suspected variable stars. TAV stands for The Astronomer Variable, plus the 1950 coordinates.

TASV hhmm+dd - TASV stands for The Astronomer Suspected Variable, plus the 1950 coordinates. The Astronomer Variable star page can be found at this url: http://www.theastronomer.org/variables.html

XTE Jhhmm+dd - These are objects detected by the Rossi X-Ray Timing Explorer Mission. The primary objective of the mission is the study of stellar and galactic systems containing compact objects. These systems include white dwarfs, neutron stars, and possibly black holes.

CSS yymmdd: hhmmss+ddmmss- This system was invented by the geniuses at the Catalina Sky Survey to completely blow your mind and to guarantee typos and errors.

The prefix stands for Catalina Sky Survey followed by the date in yymmdd form, then the coordinates in a very non-scientific and unsatisfactory format.

With more and more surveys being conducted, and more new variables being discovered, this list of non-conventional names will undoubtedly grow.

Supernovae have their own naming scheme. You can read more on that topic here: http://simostronomy.blogspot.com/2011/01/supernovae-alphabet-soup.html

Naming Variable Star Types

In a perfect world, the classification scheme for variable stars would use only those quantities that are directly observable, distinguished between physically different systems and put similar objects into well-defined groups. Unfortunately, we do not live in a perfect world, nor do we perform observations in a perfectly ordered universe, so this is rarely, if ever possible. In fact, more often than not, we actually classify stars and give them names before we understand the processes that make them variable. This of course leads to more problems down the road as better information becomes available, as you will learn.

Other classifications, such as those of Cepheids, lump together stars based on *stellar populations,* based on age, mass, metallicity, higher velocities in the galaxy and lower concentrations along the plane of the Milky Way. And yet another issue arises when we discuss binary systems, whose binarity can have a profound effect on stellar variability. So in many cases, we must now classify the *star system* also.

Furthermore, some stars exhibit more than one type of variability at the same time, so eclipses, rotational and flaring activity may be occurring at the same time!

One of the most common ways of naming variable star types is by naming the group after the first discovered or best-known case. These names are then often shortened which makes them slightly more confusing.

For example eclipsing binaries are classified as either Algol type variables, (abbreviated EA), or Beta Lyrae type variables, (abbreviated EB), or W Ursae Majoris type variables, (abbreviated EW) after their namesakes. The subtypes of dwarf novae are named after the prototypical stars of their class. UG for U Geminorum, UGSS for SS Cygni, UGSU for SU Ursae Majoris, UGZ for Z Camelopardalis and UGWZ for WZ Sagittae.

Certain classifications are broken down further into sub-groups, such as the RR Lyrae stars (RR, RRAB, RRC and RRD) and the RV Tauri stars (RV, RVA and RVB).

Other classes are named after their behavior or some characteristic. Semi-regular variables are named SR with sub-types of SRA, SRB, SRC and SRD.

Other acronyms simple stand for what they are, such as HADS, which stands for High Amplitude Delta Scuti stars.

Not only is the system for naming these types inconsistent, it also isn't well agreed upon. For many decades the General Catalog of Variable Stars has defined the "official" classification system, based on light curve, temperature, luminosity and population type. But this system is in need of revision and updating as astronomers have continued to subdivide the sub-groups into more and more specialized groups and introduced new names and acronyms into the literature.

For this course we will rely on the variable type designations and definitions used in VSX. This document, in pdf format, is provided along with the course manual as a supplemental source of information. If there is a question or debate about types, we will use this document to determine the answer. This is your Rosetta stone.

The Main Types of Variability

There are two main types of variability, extrinsic and intrinsic.

Extrinsic variables are stars where the variability is caused by external properties like rotation or eclipses. The total energy output of the star is not varying, (or is not the *primary* reason for its variability) but the amount of light we see from our vantage point on Earth varies. The main types of extrinsic variability are:

<u>Eclipsing variables</u> vary because the orbital plane of the star and its companion coincides with our line of sight to the system. As one component passes in front of the other, from our viewpoint, we see a dip in the light output.

<u>Rotating variables</u> may have any number of reasons for varying. There may be star spots that rotate in and out of view, making the star appear to fade and brighten more or less cyclically. The stars may be so close that they are tidally locked, and one star is super-heating the portion of the other star facing it, which is then reflected back into space as additional energy we perceive as a brightening each time it rotates into view. Other rotating variables may be orbiting each other so close the components are stretched by gravity into non-spherical shapes. As the stars rotate the area of their surface presented towards the observer changes and this in turn affects their brightness as seen from Earth.

<u>Microlensing variables</u> brighten, and then fade, when an object acting as a gravitational lens passes in front of the star from our point of view, magnifying the light from the more distant object.

Intrinsic variables are stars where the variability is caused by changes in the physical properties of the stars themselves. The primary types of intrinsic variability are:

Pulsating variables vary as their stellar radii swell and shrink, causing changes in their magnitude and spectrum. They may be periodic, semi-periodic or irregular in their variability.

Eruptive variables undergo irregular episodes of variability due to mass ejection or chromospheric activity.

Cataclysmic variables are generally interacting binary systems containing white dwarfs or systems that undergo large amplitude outbursts.

X-Ray variables are binary systems containing neutron stars or black holes.

The Variability Tree

The diagram below is a useful illustrative guide to all the types of variability that, more or less, follows the scheme of variability laid out in this course.

You will not be required to learn every single type listed here. This course will concentrate on those variable stars most typically observed by AAVSO observers.

From *"Variable stars across the observational HR diagram"*
Laurent Eyer and Nami Mowlavi
[2008JPhCS.118a2010E]