

Astronomy C  
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This Year! The understanding of Variability of Low and Mid-Mass Stars!  
Well, maybe you're not excited as I am....

The competition: answer lots of hard questions relating to the above. There will be Math!  
There are sections to study. First, be well versed in every area that is mentioned in the rules.  
Secondly, know all the objects listed and how we use physical laws to observe and learn about each object. Be able to find similarities and differences between all the listed objects.  
Know the Math.

Each team is allowed two, 3 ring binders, two computers or one of each.  
Even though computers are much more stable than they used to be, I'd suggest one of each!  
The batteries never run down, the internet never fails with a paper copy.  
Word to the wise!

Go "point mining". When you get your paper copy, look through it quickly, figure out where to get the most points. As an event supervisor, I've always let teams split the pages and work separately. Ask first just in case yours doesn't!

#### Resources:

Books or web sites? I like both, there are many many good sources of info on the web from sources like NASA and JPL, many from major research institutions and college courses.

I like to suggest these 2 books, both are available used from sources like Amazon for a song.

#1, The Cambridge Atlas of Astronomy, Adouze. This is a big coffee table book that contains almost everything a kid would ever need to know. It's a little dated but all the old stuff still works. There are wonderful illustrations throughout. Often these sell for \$10 with shipping!

#2, Horizons by Seeds and Backman. I used this text to teach a college course and never looked back. Older versions are just a little dated, I still use the 11th Edition. This book is filled with genius. There are sections on "reasoning with numbers" and "how do we know" that really help. My Allendale High School kids won State a few years back. I barely coached them! They used this book almost exclusively it's so well written. Really highlight each "reasoning with numbers" section. Learn to do the math back and forth. ALWAYS save yourself some algebraic pain, isolate each variable on one side of the equation so you just need to plug in data and go!

Wikipedia: Build a great folder by copying the wiki pages with diagrams and pictures for each of the listed objects. Do a good job tabbing your folder and knowing all it's sections. You can easily have too much information that you can't dig through or too little info and not have all the answers. Find a happy medium!

NASA, JPL, major institutional websites and courses.

Because much of this subject matter is new, it won't be in the text, go find it!

Apply the concepts and math from the textbook to the objects you are learning about.

It's hard to tell what each event supervisor will think is important. In my 35 years doing this, I quickly learned that it was my job to guess what would likely be on the test. Some event supervisors will give you a quick idea of what they expect if you ask. It's worth a try!

In order to understand how things formed in the Solar System and elsewhere, it's important to understand how the Universe formed. For Division B, it's pretty simple. The Universe and its laws formed just prior to the Big Bang. The initial Universe was very hot and filled with large particles that no longer exist (except in particle accelerators able to reproduce that early temperature). As it cooled, smaller and more stable particles formed. Eventually we ended up with a Universe of almost entirely Hydrogen, the simplest element. That Hydrogen formed clouds through gravitation. Those clouds formed the first stars and planets. Stars fused Hydrogen into larger elements then blew up and scattered those into the interstellar medium to be drawn into new stars and planets. New stars took more Hydrogen plus those larger atoms and made even larger ones. As Sagan said, "we are star stuff"!

All of those stars also formed clusters and galaxies, bound by gravity along with many many minor and major planets of all sizes and compositions.

You should know the "7 states of matter". We could argue about that, some people would say 4, some up to 12. For astronomy 7 are fine! As we warm up, changes of state occur. Every different atom or molecule goes through these changes of state. They all transition at different temperatures. From those temperatures, we can identify each one.

Bose-Einstein Condensate. Only happens near absolute zero. Groups of atoms enter the same quantum state and "do the Macarena", all acting like a big atom that can be observed.

Solids. Orderly group of atoms bound tightly together. You can think of a chunk of metal as "iron or aluminum ice". Everything "freezes" at a cold enough temperature.

Liquids. Loosely bound. Again, each atom or molecule has a melting / freezing point that's specific to it.

Gas. Unbound, free to fly around. Sometimes the transition from solid to gas has a short liquid phase or almost none at all.

Electro-Magnetic Plasma. When you continue to heat things up, you cause electrons to change orbitals. This produces the Electro-Magnetic Spectrum including visible light. Atoms release photons of very specific colors / wavelengths for each electron energy level jumped. From this we can tell exactly what something contains and at what temperature. Radio and optical astronomy uses spectroscopy to determine conditions in a star or other radiation source. It also works in reverse. Each element absorbs very specific wavelengths of photons. If we look at a distant star and record it's spectrum, we will see "dark lines" from gasses between us and stars.

Weak Nuclear Plasma. Nuclei, Protons and Neutrons are ripped out of atoms (think atomic bomb). It takes a bunch of energy to get it started so it only happens in very high temperatures. Fusion in the Sun or other stars involves the Weak Force.

Quark-Gluon Plasma. Protons and Neutrons are torn into their composite Up and Down Quarks. Super high energy situations only!

In Solar (stellar) systems, these states are very important because of “fractioning”. Since each atom or molecule changes state at specific temperatures, distance from the star matters a lot. Some atoms may be solids, liquids or gasses depending upon temperature. We are fortunate enough on Earth that water is liquid on our planet. The Solar (stellar) wind blows light atoms away from the closest planets, those atoms slow down and gather to form gas or ice planets or cometary nuclei. There are “bands” of different composition all around a star. Each object forms from that material. Rocky planets are made of heavier material and can exist closer to each star.

You should also understand the 4 forces in nature. They relate directly to the states of matter.

Gravity. By far the weakest force! It takes lots of mass to have much gravity. On the other hand, gravity may be weak but it travels across the entire Universe! Mediated / carried by the Graviton.

Electro-Magnetism. Next weakest force but responsible for holding atoms together. Particles, mostly Protons and Electrons, can have a positive or negative charge. Electrons are held by the Protons in orbitals around the nucleus. Light can travel across the Universe but it can be slowed down or bent by gravity. Mediated / carried by the Photon.

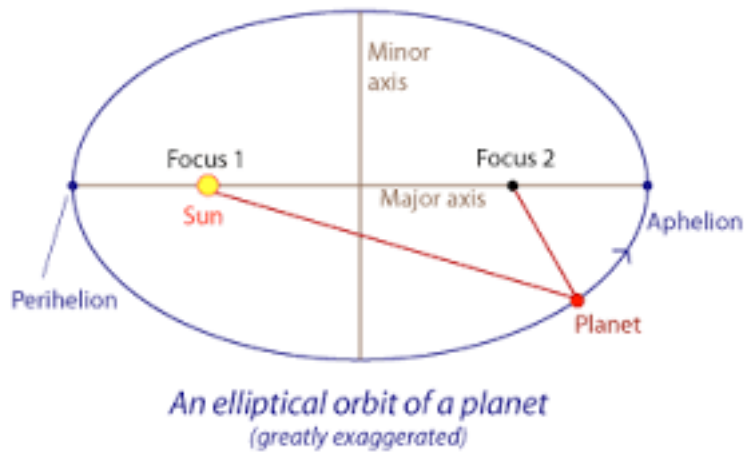
Weak Force. Holds Protons and Neutrons together in the nuclei of atoms. Not really that weak but its effects only span the size of the nucleus. Breaking the Weak Force means that the temperature is pretty hot! Mediated / carried by Intermediate Vector Bosons.

Strong Force. Holds Protons and Neutrons together. Protons are made of 3 Quarks, 2 “Ups” and a “Down”. Neutrons are composed of 2 “Downs” and an “Up”. They are held together by the aptly named Gluons! The Strong Force only works in an area the size of Protons or Neutrons.

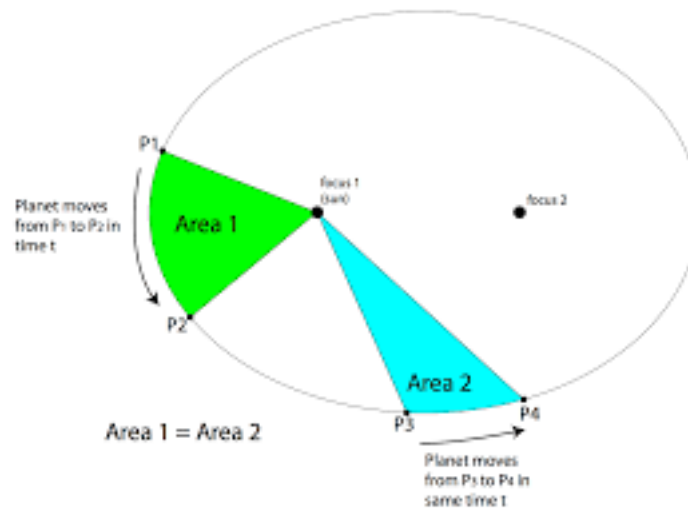
Again, changes in each state effect each level / force. We don’t experience much beyond Gravity and Electro-Magnetism on a daily basis. In very high energy situations like Neutron Stars and Black Holes, things get really hot and we detect the release of high energy particles. Changes in state are important separators in stellar systems.

Kepler’s laws. Kepler took Brahe’s excellent observations and turned them into simple laws that explain orbital dynamics.

#1, Orbits ain’t round. Though it’s possible for a perfect, circular orbit, chaos says it won’t happen very often. Orbits are ellipses. There are two focuses in an ellipse and the star or planet will be at one of them.



#2, Planets sweep out the same area in equal times. Imagine having a pie to cut up into 12 equal size / mass pieces. If the center is off to one side, one side will have short, stubby pieces, the other, long skinny pieces. Everyone (each month) gets the same amount of pie! Comets move really fast when close to the Sun. When they are farther out, they slow down.

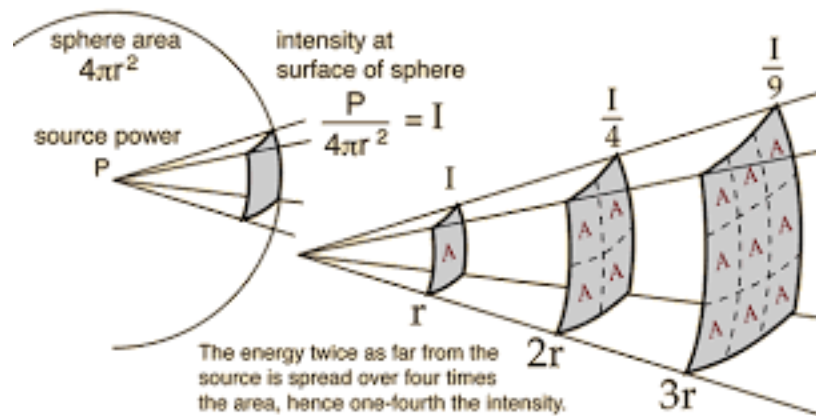


#3,  $P^2 = A^3$ . The orbital period of the object in years squared equals the orbital distance in astronomical units (AU) cubed. I can't seem to find a good example or a way to rewrite the equation on my computer (oh for the days of chalk on a chalkboard!).

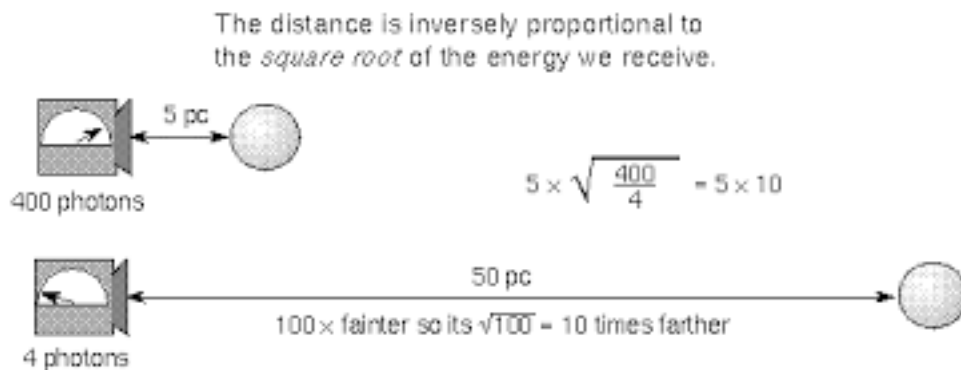
I like to reduce it to 2 equations. If you want the period and have the distance:  $P$  equals the square root of  $A$  cubed. If you want to know the distance and have the period:  $A$  equals the cube root of  $P$  squared.

Let's look at Jupiter as an example. If Jupiter's distance from the Sun in AU's is 5.2. Cubing 5.2 we get 140.6. The square root of 140.6 is 11.8. Therefore Jupiter's "year" is 11.8 years.

If we take 11.8, square it and then take its cube root, we get 5.2 AU's from the Sun. Next, the Inverse Square law! Light or radiation decreases as the inverse square of the distance. Let's say we have a light bulb with a photo cell 1 meter away. The amount of light is  $1 / 1^2$  or 1. If we move the detector to 2 meters, the amount of light is  $1 / 2^2$  or  $1/4$  the light at 1 meter. At 3 meters we see  $1/9$ th, 4,  $1/16$ th etc.



When we look at a star, we can see from its spectrum what elements are “burning” in it. We can also derive from that its temperature and intensity, they are all related. If we know how bright a star is, we measure how much we see here on Earth. From that we use the inverse square law and we can determine distance very accurately.



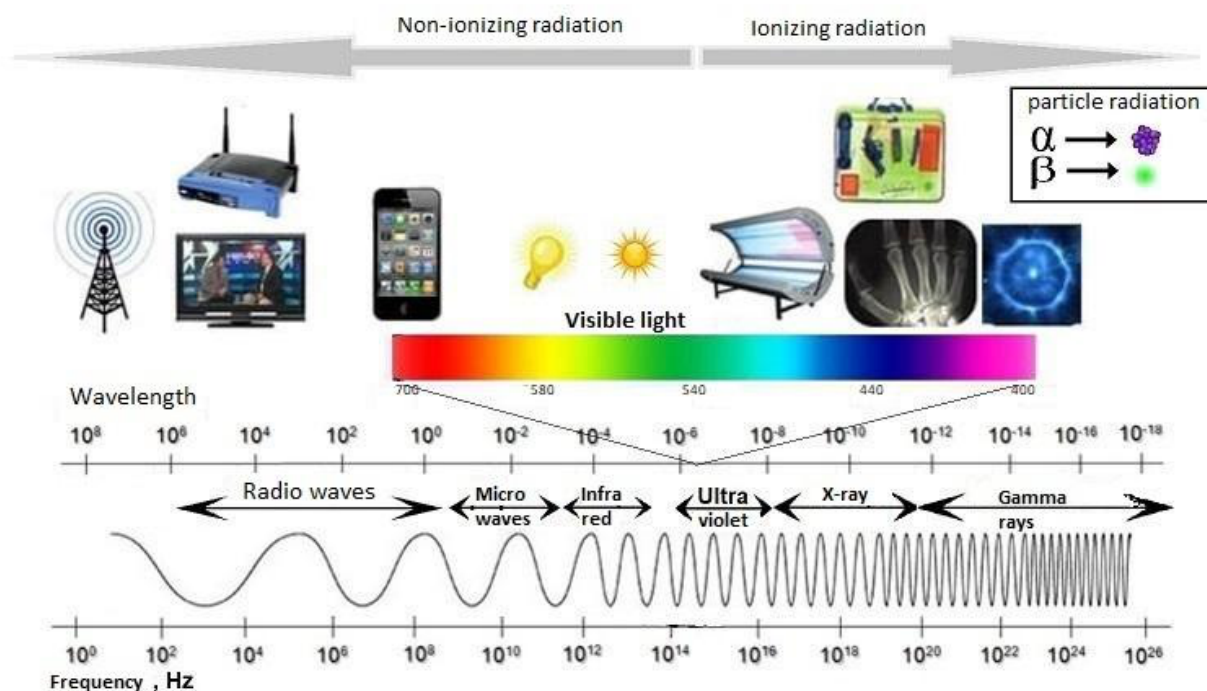
$$b = \frac{L}{4\pi d^2}$$

$b = \text{apparent brightness in } W / m^2$

$L = \text{Luminosity in } W$

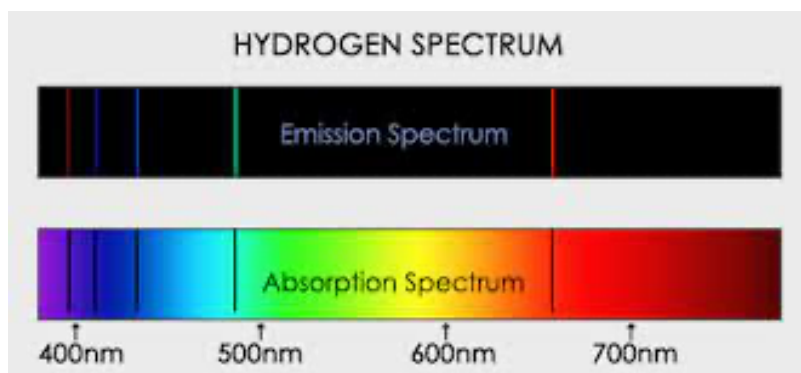
$d = \text{distance in meters}$

# The electromagnetic spectrum



As temperature goes up, wavelengths become shorter and have a higher frequency. Non ionizing radiation does not tear apart matter. Ionizing radiation does. Long wave ultraviolet gives you a suntan. Short wave ultraviolet tears apart atoms in your cells or DNA, doing damage. X-Rays can be worse, Gamma rays go through pretty much anything unimpeded!

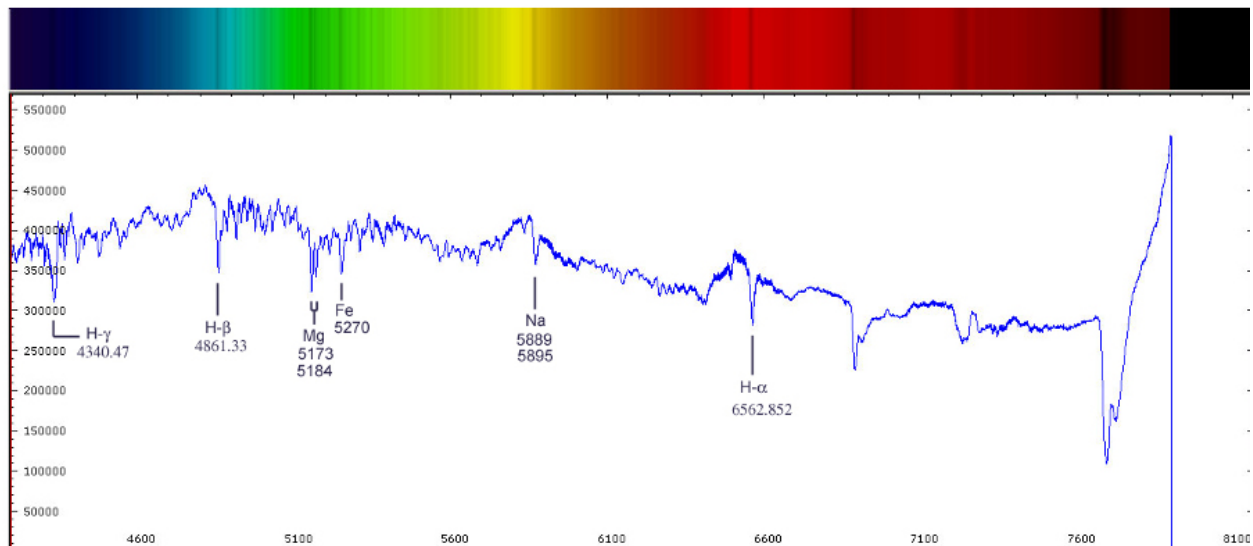
Remember to relate this to the elements, atoms and molecules. Every different atom or molecule releases different wavelengths at very specific different temperatures. Atoms also absorb very specific wavelengths.



There are two types of spectral lines, bright and dark. Bright lines happen from the emission of photons. Dark lines from absorption

This is a good stellar spectrum and graph that show brightness and wavelength.

From it we can see dark lines for Hydrogen alpha, beta and gamma, Magnesium, Iron and Sodium along with the bright lines from emission.



Variable stars. Long ago they were called “Demon Stars” because they came and went, sometimes simply brighter or dimmer by a little bit, sometimes completely disappearing.

The Association of Variable Star Observers or AVSO has been around making observations for a long time. Many astronomers got their start by checking out stars and measuring their brightness changes over days, months or years. Look up their web site and read about variables and their history!

Variable stars are in a place in their lives where they are unstable. Stars have two forces that work on them. Gravity, based on their mass and Fusion from nuclear reactions.

In a stable star, they equal out and the outer envelope of the star remains the same size.

In variables, the star becomes cooler, gravity takes control and the star contracts. When the star contracts the atoms get closer together and fusion takes over, the star expands. Eventually, it cools again and collapses then expands over and over.

What is really cool is that the rate of the star “blinking” is related to its mass and brightness. So, if we know how bright it really is and how much light we receive at Earth... Inverse Square Law! Boom, we know it’s distance!

We determined the first distances to galaxies and globular clusters by isolating variables in the 'scope and measuring their apparent blink rate and apparent brightness. We then learned to use Supernovas as guides, they also have specific brightnesses.

Other suggestions for Math. Some may be used, some not. Be prepared!

Know Kepler's 3rd. If two stars orbit each other, their periods lead directly to the distance between the bodies.

Understand Black Body Radiation. Things at various temperatures emit a wavelength of maximum intensity.

Inverse Square Law. Radiation drops off as the inverse square of the distance.

Doppler Formula to determine radial velocity. The difference in the wavelengths of light between the leading (coming toward us) side versus the trailing (moving away) side gives us how fast the star is spinning.

Parallax and Distance. As we orbit the Sun, we take observations from both sides. Object in the foreground and background move relative to their distance.

Absolute Magnitude. Tells how bright a star really is.

Luminosity, Radius and Temperature. The amount of light a star emits is based on its temperature and size.

Masses of Binary Stars. Related to Kepler's 3rd but including mass.

Mass-Luminosity Relationship. A star's luminosity in terms of the Sun's luminosity is its mass raised to the 3.5 power.

Life Expectancies of Stars. Time equals amount of fuel / consumption.  $T = M / M^{3.5}$ .

At this point, it would be impossible for me to cover every concept or object listed in the rules. That would be 3-4 semesters of college classroom experience.

Read. Read some more. Always look up words you don't understand. Remember that the best teams treat SO like a spelling bee, practicing terms over and over. You can't just expect to look up things during the test.

Build quizlets.

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Good Luck!

If you have any questions, feel free to message me.

