**Lesson 1: Brightness!**

Astronomers generally use the HR diagram to either summarise the evolution of stars, or to investigate the properties of a collection of stars.

Think Tank:

Earlier we spoke of spectral classifications: specially when we spoke about Annie Cannon and spectral classes: An **M**-**type star** is within the **M class** a spectral **class** indicating **stars** with very weak hydrogen absorption lines and with molecular lines (particularly titanium oxide), a red color,

and a surface temperature in the 2400-3700 K range. Let us look at cool M-class stars as an example. If you hear or look at the sensorial H-R diagram we can perceive that in fact there are three main groups of these stars. Each spectral class sounds like a membrane and the divisions from one spectral class to another sounds like an orchestar harp, when a star For Breezy and Shirin if we use the diagram below the explanation may be like:

description of auditory diagram: for the stars on the list:  
Visual diagram from: Antares and Betelgeuse. Again, these stars are cool, but they are extremely luminous, almost 10,000× as luminous as the Sun. *Why do these three groups differ so much in luminosity?*

Answer: The answer to this question depends upon the Stefan-Boltzmann relationship. You may recall from the equations we studied earlier that the energy emitted per unit surface area per second is simply a function of the fourth power of temperature, that is written in the form:

*l* ≈ *σT4*If two stars have the same effective temperature they each have the same power output per square metre of surface area. As the H-R diagram however shows that one is much more luminous than the other it must have a greater total power output therefore must have a much greater surface area - the more luminous star is bigger. We can infer this from the full expression for luminosity in the equation: Stellar Luminosity (energy emitted per

second) is therefore: the Stefan-Boltzmann Law which is Stefan Boltzmann constant by the fourth power of the temperature multiplied by the area which is four multiplied by pi multiplied by the square of the radius of the sphere in written form (add alt text and mathml) ( do not make them go back to search for it) . In written form it is:

*L* ≈ 4π*R2σT4* 9898  
L is the luminosity, R is the radius, T is the surface temperature, pi = 3.141

and

σSB = 5.671 x 10-8 Watt/m2 K4  
We need an HR diagram to explain the different regions

Axes on the H-R Diagram

This points to an interesting and sometimes confusing feature of the H-R diagram - the scales on the axes. 1) effective temperature does not increase as it goes from left to right, it actually decreases, that is the highest temperature is on the left-hand side. If colour index (Blue-Visual) rather than effective temperature is used then it goes from negative (blue) on the left to positive (red) on the right. A third alternative along the horizontal axis is to use spectral class. Of course, all three quantities are essentially showing the same thing. ( working on auditorily extended examples of the axes)

The vertical axis displays the luminosity of the stars. This is either as a ratio compared with that of the Sun or as absolute magnitude, *M*. One point to be careful of when using absolute magnitude is to remember that the lower or more negative the absolute magnitude, the more luminous the star. The brightest stars therefore appear at the top of the H-R diagram with the vertical axis having the most negative value of *M* at the top.

In some circumstances, such as when plotting stars apparent magnitude, *m*, or *V*, rather than absolute magnitude may be used. This is valid as for example in clusters. A cluster is a group of stars that share a common origin and are gravitationally bound for some length of time. Then all the stars in the cluster are taken to be at the same distance away from us and then any differences in apparent magnitude are due to actual difference in luminosity or *M*. Diagrams where *V* is plotted against colour index, B-V, are also known as colour-magnitude diagrams.

Here we have a list of 8 stars in the orion constellation. The list contains the absolute magnitude, temperature, and Luminosity. A mapping of those parameters using Volume, and Rhythm is also provided. for the volume mapping ( meaning that the active parameter changing in the data stream is volume) Absolute Magnitude has been mapped in volume using the sound of a woodBlock, Temperature has been mapped in volume using the sound of flute and the temperature has been mapped in volume using the sound of a nylon string guitar. Remember that in the case of the absolute magnitude the more negative or lower the volume the higher the absolute magnitude is. For the other two parameters the changes are directly proportional to the value. ( the higher values higher volume). You need to adjust your system audio to be able to hear some of the numbers. An additional sonification provided is all those values together. The mapping in rhythm is also provided same timbres or instruments. For rhythm mapping you will notice that the amount of beats for the absolute magnitude diminishes. this happens because the program used to translate the data to sound ……

use the equations provided earlier in the chapter ( stefan=Boltzman ) to calculate the radii and the area of the star. Plot them in the HR diagram. Identify the evolution stage of each star. Do you identify any patterns for example clusters of colder stars or clusters with colder (redder and older) stars? of stars or clusters with younger stars ( bluer, younger) Hint: open clusters which are also a place for stars to born.

The temperature of a star can be calculated directly from the B−V index, and there are several formulae to make this connection. A good approximation can be obtained by considering stars as blackbodies using Ballesteros' formula:

Image

*A*, *B*, *C* and *D* are the magnitudes of the stars measured through filters with frequencies *ν*a, *ν*b, *ν*c and *ν*d

**where K is determined as:**

Image

where the triangle on the equation is the greek letter delta and means a change in the magnitude of the star using the the filters.

that equation may be reduced to:

Image

Use the orchestar on the telescope to determine B-V for each star, calculate the temperature, complete the table below , plot the stars on the HR diagram.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| name | number | abs Mag | Temperature | Luminosity | emissivity |
| Betelgeus | 1 | -5.85 | 3600 | 126000 | 1 |
| Rigel | 2 | -7.84 | 12100 | 1.2 | 965 |
| Bellatrix | 3 | -2.78 | 21800 | 9211 | 1 |
| Mintaka | 4 | -5.8 | 29500 | 190000 | 1 |
| Alnilam | 5 | -6.89 | 27500 | 537000 | 1 |
| Alnitak | 6 | -4.1 | 29500 | 250000 | 1 |
| Saiph | 7 | -6.1 | 26500 | 56881 | 1 |
| Meissa | 8 | -4.25 | 35000 | 165000 | 1 |
|  |  |  |  |  |  |
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go to <https://www.opticsthewebsite.com/OpticsCalculators>

input the temperatures and generate two blackbody curves for each of the sources on the table. Download the result as a CSV. You may also use your word processor ( like notepad or pages to save it as a. txt file and generate the text output. turn in the sonified Blackbody curve : photons vrs wavelength and watts vrs wavelength. ) the link provided above also provides the visual image. we are more interested in the auditory output.

lessons 2 and 3 on Dust

lesson 2 (DUST):

The fate of all that dust?

You may want collect dust around your house, and scrutinise it to determine its origins and think what may it become in the far future of that dust if it is not disturbed by humans?

if possible you may want to study its texture ( you may do that visually or by touch being careful if you have any allergies), if there are no sensitivities you may smell it, classify it by size, colour , density, or other characteristics that may help you to guess in an educated what will be the evolution path of that dust. Using your light detector and.or orchestar as it will give you the colour, we challenge you to create an HR diagram of that dust and scientifically evidence the evolution path of the dust you have collected. and line out the possible evolution of it. Keep the dust to check if we may use an initial mass ( kind of using jeans mass with this...let's check) even take pictures and send it to the lecturer and open discussion. Group the particles, find a way to approximate its mass (i.e. either by counting or fitting the dust to different cubic containers and doing an unit exchange for example 1 cm3 / cc = 0.001 kg wt.), they may plot it, perhaps using the the telephone light detector app and plot obscuration vrs mass and predict its obscuration and extinction over the years and the factors influencing it//. Hint, you take your dust, or your particles and you organise it by size, colour, scent, or other and try to emerge with what is the origin of it? and extrapole to what it may become of it? ....

Experience 2 Scattering

We mentioned earlier that dust scatters light. Even the dust in the air we breather scatters light and we breath about 50 billion particles per hour (<https://www.npr.org/2013/03/18/174592712/scientists-catalog-individual-dust-particles?t=1651505469341>). The dust scatters light like xray photons, and this hs been used to relate extinction, gas column, and distance (Predehl & Schmitt 1995, Valencic & Smith 2015).y. Astronomers calculate the probability of a photon being scattered in a particular direction by a dust grain orthe dust scattering cross section——which depends very strongly on the angle at which the photon interacts with the dust grain and the outgoing angle of the scattered photon. Scattering is restricted to very small angles. So this is like saying: I want to understand dust ( our object) to understand scattering and do astronomy with it i need to throw something to the object and check how the shooted thing either bounces back, or passes through ( if we would be talking about quantum physics it could do both at the same time…but we are not touching quantum physics). In this case we are throwing light to this potential ( the dust). hmmm we are throwing light …photons..and a photon may be scattered many times before being transmitted …if it does so…we will limit ourselves here to the simplest case…just in a plane throwing one photon to the scattering dust. Because my dust, my potential (( the one i am interested on) is localised to some region this means that my potential goes to zero as i move to infinity. Because the the potential goes to cero, the energy of the state is given by, E = (h^2) (wavelength or wave number ^2) divided by 2M. For our case and because we are not using quantum physics yet, we will consider the wavelength (λ) of the incident radiation (in our case xrays)• (2) The size of the scattering particle and the number of particles N ( reffer to page ? for how to calculate), usually expressed as the non dimensional size parameter, x: and R the radius of a spherical particle, λ is wavelength.

x = 2(pi)r/(wave length ((lambda) )

calculating x we observing how the light ( in our case X-rays are scattered and determine what particles scattering regime taking place in that dust. : Rayleigh scattering • x ~ 1 : Mie scattering • x >>1 : Geometric scattering much less than 1. of course we are using the least complex example to get us started.

As you noted from the experience on observations using different tracers such as dust. ...or other abundant molecules. you may use the frequency and/or wavelength of molecules or elements to indirectly estimate the amount of molecular hydrogen. They can be observed in the radio wavelengths by observations of molecular lines, or using another technique that is called dust extinction.

So why the author had me collecting dust from my home? When I did that the first time one student in ZA asked me if I had asked them to do that because I had spoken to his grandparents! We did that because from the beginnings we may extrapolate to possible evolution paths!

**Let's calculate the mass of hydrogen in the galaxy**

As according to these studious people, the potential for star creation is related to the amount stellar dust, formation of molecular clouds and later, today as you will see it is associated with the mass of a star. Let's check if we can calculate or approximate the amount of hydrogen gas in a spiral galaxy. As you know the light from distant stars and more distant galaxies is not featureless, but has distinct spectral features, that are characteristic of the atoms in the gases around the stars.   
The apparent change in wavelength of light caused by the motion of the source, observer or both is known as the Doppler Effect. In other words, ....The Doppler effect or Doppler shift (or simply Doppler) is the change in frequency of a wave in relation to an observer. Waves emitted by a moving object as received by an observer will be blue shifted (compressed) if approaching, red shifted (elongated) if receding. It occurs both in sound and light. How much the frequency changes depends on how fast the object is moving towards or away from the receiver.

{expand example of people that work collecting trash, and the ambulance}.  
In the 1920’s Edwin Hubble discovered that there is a linear relation between the velocity of a galaxy and its distance. Galaxies that are further away are moving away faster. Recessional Velocity or velocity of the galaxy away from us = Hubble's constant times distance

V = Ho D  
Where  
V is the observed velocity of the galaxy away from us, usually in km/sec  
H is Hubble's "constant", in km/sec/Mpc  
D is the distance to the galaxy in Mpc

Right now, on link #? you are sensorially perceiving a spectrum or a plot of the intensity of light at different frequencies or wavelengths.

Light is given off at a specific frequency by an atom or molecule. Every different type of atom or molecule gives off light at its own unique set of frequencies; thus, astronomers

can look for gas containing a particular atom or molecule by tuning the telescope to one of the gas's characteristic frequencies. For example, Hydrogen 1.4 GHz or 21 cm wavelength.

On link? you will find a sonified/visual and on hardcopy on your desk a tactile double horn profile of the tactile HI spectra from Arecibo Observatory and define what each axis represents.

Possible explanation

In a hydrogen spectrum of a spiral galaxy, there are peaks because the gas is rotating around the nucleus of the galaxy. Hydrogen in the Galaxy is more concentrated in the nucleus and the spiral arms and less concentrated elsewhere.

The Y-axis is the intensity in units called Janskys and the X- axis is the velocity in km/s. In this activity you may obtain two measurements from the graph: the area under the curve, and the central velocity of the spectral line.

5. Using a foam Cartesian Plane like the one used for the HR diagram or graphing paper or computer for the display and will ask the students to reproduce the Graph on it (just reproduce the double horn profile).

a. Answer the following questions ( doing tactile exploration and graphing paper… by listening roger from the UK is figuring it out)?

i. What is the value of 1 division on the horizontal?

ii. What is the value of each division in the vertical?

iii. What is the width of the spectral line?

iv. What is the value of the velocity at the center of the spectral line (v)?

v. What is the area under the graph?  
1. Count the squares under the curve  
2. Area= # of squares x (value of one division on the

horizontal) x (value of 1 division on the vertical). vi. Calculate the mass of the galaxy.

Mass of hydrogen in the galaxy ~~ Mass of the galaxy MHI = (2.36 x× 105) x D2 x AREA  
This relation gives the mass of the Galaxy in Solar Masses.

1 Solar Mass = 1.989 x 1030 kg  
For the Distance, D, use Hubble’s Law: D = v/H

H= 70 km/s Mpc

Find the distance to the galaxy in Mpc (v=Hd use H= 70 Mpc km/s)

Find the mass of the galaxy  
M(HI) = 2.36 x 105 x d2 S(v) dv  
Mass(in Solar Masses) = 2.36 x 105 x d2 x area

d= distance centre distance divided/H ====

d= v/H and

(Remember: velocity = distance/time; time= distance/ velocity; distance = velocity x time)

If using audio area: frequency beats/measure = Jy Km/S show equivalence ( measure and signature is quarter notes in 1 minute, we want it in seconds a minute is 60 seconds)

Example of UGC05957 using the audio equivalent and or tactile glue spectra

Width= 500 km/s  
1 div in horizontal axis = 100 km/s 1 div in vertical = 0.001 Jy Velocity= 4330 km/s  
Area= 30 x 100 x 0.001 ~ 3 Jy km/s

Distance = ~ 4330 / 70 = 62 Mpc

(MHI = 2.36 x 105 D2 FHI mass of atomic hydrogen in M⊙ given D, the distance in Mpc and FHI, the 21 cm flux integral in Jy km s-1)

then:

Mass = (2.36 x 105) x 622 x 3 = 2.7 x 109 solar masses

**Lesson 5 solar activity from NOAA and lesson 6 a plot and mass of a CME**

The solar activity increases with sunspot number, perhaps the most significant property of active regions is their magnetic field. White light features that are known as photospheric faculae are brightening that mark active regions. The enhanced brightness is from greater temperature and densities than those found in nearby regions of the photosphere, similar to the chromospheric plages. The plages float in the chromosphere above active regions in the photosphere. Perhaps we are repeating ourselves from earlier but plages are areas in which the temperature and density are higher than in the surrounding chromosphere and are caused by the magnetic fields of the active regions. ( sound) In many aspects when you hear them as you scan image number? or letter? with the orchestar or the light detector of your telephone you will perceive them as intensifications of the chromospheric network. During active times large ejections of mass, called coronal mass ejections disrupt the corona. These huge bubbles or clouds of gas containing billions of tons of solar material travel outward so forcefully that they cover millions of kilometres within a few hours. The coronal mass ejections are the most energetic event in our Solar system, yet their cause is suspected to be a gradual revolution of coronal magnetic fields into an unstable arrangement (sound). But among the most puzzling spectacular and energetic phenomena associated with active regions are solar flares (audio). These are outbursts that liberate beyond gigantic quantities of energy and radiate energy at many frequencies from the x ray and gamma rays to long wavelengths radio waves; they emit high energy particles called solar cosmic rays. This solar activity (Flare x rays and ultraviolet radiation) adds to the solar events that may disrupt terrestrial radio communications by disturbing the earths ionosphere. The high energy particle cords reach the earth in 30 minutes and remember that clouds low energy particles require from 6 to 24 hours to transit from the sun to earth…) ( tactile sun with the sounds)

Let's do an example: ( go to:  
NOAA: https://www.swpc.noaa.gov/products/solar- cycle-progression

Image Image

https://www.swpc.noaa.gov/products/lasco-coronagraph

The amount of radiant energy emitted by the sun is called solar radiation, While solar irradiation refers to the amount of solar radiation received from the Sun per unit area which is expressed in (kW/ m2).

**Lesson 6** to open up good fun lesson I found somewhere and found it good for the book (ref):

we will plot data from the solar cycle of the Sun. The students will relate selected solar cycle periods to periods on earth, in your country, your city, the teams will search and find (i.e., periods of draught, periods of high precipitation other things..farming... occurrences of diseases, migration of animals, precipitation… anything they should use their creativity and in groups they will write a 2-page document trying to convince the government to invest money in possible ways to prepare for the next solar cycle. At least in total 800 words, doubled spaced. Be creative but you need to sustain your argument with valid evidence.

\*\*\*\*\*\* solar cycle and temperature\*\*\*\*\*

Does the solar cycle have an effect on climate change?

bring evidence i am not answering that here but it has to do with where, when and how the irradiance from the sun is having an effect and compare on how with time the temperatures at the higher and lower atmospheres change.

**lesson 7: the mass of a coronal mass ejection:**

In the dust chapter we wen over scattering.. Scattering is a process that occurs when an electromagnetic wave collides with a particle. that collision removes removes energy from the incident wave and re-radiates the energy and for instance it is scattered. It is scattered because the the electric and magnetic components of the incident wave accelerate the particle which emits radiation. Thomson scattering is an important phenomenon in plasma physics and was frst explained by the physicist sir John Thomson. The main cause of the acceleration of the particle will be due to the electric feld of the incident wave. The particle will move in the direction of the oscillating electric feld, resulting in electromagnetic radiation. As a hint the moving particle radiates most strongly in a direction perpendicular to its motion and that radiation will be polarized along the direction of its motion. Therefore, depending on where an observer is located, the light scattered from a small volume=element may appear to be more or less polarized.''

''Compton scattering or the Compton effect, is the decrease in energy (increase in λ) of a high energy (X – or γ – ray) photon, as it interacts with a free electron. More important for astrophysics, is the existence of the Inverse Compton scattering. In Compton scattering the photon gains energy (decreasing in wavelength) upon interaction with a high energy electron. The amount the wavelength increases by is called the Compton shift. Although nuclear Compton scattering also exists, what is meant by Compton scattering usually is the interaction involving free electrons.

On chapter 3 and also in this chapter we learnt about the mean free path and scattering. As photons are scattered in random directions, i.e. random walk in which each step is the mean free path which mathematically is described as the mean freepath is equal to λ = 1 σT ne. Do not forget that. Now, Imagine that the celestial sphere is an imaginary sphere of immense radius surrounding you the multi-sensorial observer. The plane of the sky would be a plane that touches the celestial sphere, but do not cross it at that point, that means it is tangent to the celestial sphere and perpendicular to your face if you turn it towards the source ( do not look directly into the sun). Lets use the CARDIS, find the x,y,z axis, take the z-axis to run along the line facing an object (people call it the line of sight), then the plane of the sky will be the plane slicing throught the x-y plane note that the way the x,y, axis connect to the z axis is perpendicular to the z-axis. In the case of LASCO, measured distances in solar radii are actually measurements of elongation, where elongation is the angle between the Sun-Earth line and the line from the Earth to the measured point P.

Use the provided txt data from a CME and convert it into sound using your favourite sonification prototype. If desired also reproduce the plot in the Cardis/.

1. Light from P, which is the measured point, is Thomson scattered such that the line from the Earth to P ( the measured point) is at right angles to the line from the Sun to P. This approximation can be expressed as R is approximately the sine of the elongation or in graphemic form:

R∼ sin ε ( greek letter careful for nemeth or duxburry or mathML

in that equation R is the distance from the Sun to P in stronomical units. Assuming that the mass of the Coronal Mass Ejection (CME) is localized in the plane of the sky. and if the integrated line of sight intensity is equal to the CME intensity at the point P being measured.

2. .Elongation angles or angle between the two perception lines, or between two point objects as perceived from an observer are small, such that the sin of the elongation approximates the size of the elongation in graphemic form (sin ε ∼ ε), for instance R is approximately the elongation in graphemic form (R∼ ε).

Then , even though we know this does not apply in all cases and only under those two assumptions, we may use Thomson scattering to approximate the mass of a coronal mass ejection. A CME is tremendously accelerated flow of particles ejected from the Sun but the interstellar media is filled with particles. The electric and magnetic components of the wave crashing on those particles in the interstellar media accelerate the particle. As it accelerates, it, emits radiation and the incident wave is scattered this means that the incident wave causes further vibration in the electrons in the interstellar media and those electrons will emit light in all directions. The main cause of the acceleration of the particle will be due to the electric field component of the incident wave. The moving particle radiates most strongly in a direction perpendicular to its motion and that radiation will be polarized ( restricted to a plane ) along the direction of its motion. Therefore, depending on where an observer is located, the light scattered from a small volume element may appear to be more or less restricted to a plane (polarized).’

So for our sky plane assumption, the CME mass (m) is calculated by measuring the integrated intensity across a selected area on a running difference image βobs. We may also use a new concept of gravitational redshift. A gravitational redshift occurs whenever light moves from a stronger to a weaker gravitational field. … as a shock of particles moving away from the strong gravitational field of the sun. … As the particles does so, they do work because ( and assuming this is this is only a bunch of electrons and photons) it has an equivalent mass as given by the equation energy equals mass multiplied by the square of the speed of light E = mc^2. Then a gravitational field can affect it. In such a situation, an ordinary particle loses kinetic energy (as it gains gravitational potential energy and slows down. Photons cannot slow down….. they travel only at the speed of light. Instead of slowing down, a photon's loss of energy shows up as a decrease in its frequency (an increase in its wavelength), that is, as a redshift, because as you may remember from previous chapters energy equals the frequency (v) multiplied by the plank constant. E = hv. But in this case we are limiting ourselves to electrons.

we also know that v in this case is frequency and that frequency is one divided by time. at any point we may have a calculation of frequencies and we may observe the frequency differences ( if at all from one point to another).

using the coronal mass ejection data provided in the archived link to this page sonify the and use the relation frequency beats/measure = intensity on Y (time difference) show equivalence ( measure and signature is quarter notes in 1 minute, we want it in seconds a minute is 60 seconds). First as we did previously, auditorially or if tactile adapted, count the divisions under the CME intensity curve and the divisions from the base line to the highest point on the intensity curve (y). Identify the beginning of the CME on the chart and the end of it by identifying when your mapping starts increasing and ending. Calculate how many beats ( at one tempo) from the first increase to the end of the CME. That will give you the width of the intensity curve. Using those numbers calculate the area under the curve.

as our values are over time… we may calculate frequencies and from those frequencies we may calculate the mass and the energy of the. CME.

challenge use the following relation to. calculate the mass of electrons in a CME:

mass equals Energy divided by the square of the velocity of light or

m= E/c2 (nemeth) eq letter? or number ?  
which is equal to = hv (initial)/c2 ([reffer this to the equation discussed earlier conceptualised equation #?  
if on equation # or letter ? we substitute for one of the masses then the multiplication of the plank constant by the change in frequency is equal to the negative of the universal gravitational constant multiplied by the ratio of the product of the plank constant multiplied by the initial frequency divided by the square of the velocity of light and multiplied by the Mass over R which is the radius of our source the Sun. We need to do this because we do not have the mass yet.   
in mathematical graphemic form that will be:

h(change v) = - G((hv(initial))/c^2)M)/R nemeth eq# or letter ?…

We may just move all the frequency terms to one side of the equation then as a result we get that the change of frequency over the initial frequency is equal to the result of the multiplication of the negative of the universal gravitational constant multiplied by the result of the mass divided by the multiplication of the square of the speed of light by R. ( conceptual equation number ??? or letter ????)

in mathematical graphemic terms it is:

(the change v)/v(initial)=-GM/c2R

from the chart or the sonified data

what is the value of v(initial)

what is the value of vfinal

then the change of v is \_\_\_\_\_\_

Now clean the equation for M and calculate the mass

what is the value. of M?

what is the value of E? ( remember E=mc^2)

this is considering that is only electrons or regular particles.

**Lesson 8 Determination of mass of binary systems.** ( this lesson is inspired on the nasa web page and chandra way of calculating the masses using Kepler)[credits]

Let us now try to apply these to determine the total system mass and the mass of the individual component stars. We still working on representation ? After careful sensorial examination we find that:

In this system the mass of A is larger than the mass of B in mathematical graphemic form is written as mA > mB.  
The barycenter or centre of mass of the system is where the multiplication of the mass m of star A by the distance between the baricenter to star A or rsuba is equal to the multiplication of the mass of star b msub b multiplied by the distance between star B and the baricenter rsub b. in mathematic graphemic form is written as:

mArA = mBrB (eq #1 or letter a? ) ( Nemeth)

as reference:

the distance from the center of star one to the center of the second star is the total radial distance. The total mass is the sum of the mass of star one plus the mass of star 2 in mathematical graphemic form is below. we need an original drawing for this.Image

This is great because we may then determine r sub a and r sub b. for example if we leave rb alone:

for example rsub B = r - rsubA below is written in math graphemic form (eq # or letter a? )( Nemeth) this is to obtain r sub b

i may substitute what r sub b is equal ( we just said it is equal to the subtraction of rc minus ra on the equation # or letter ? ( 1 or a).

then that will be converted into the mass of star a multiplied by r sub a is equals to the mass of star b multiplied by the result of the subtraction of r minus r sub a. in graphemic form it is written as:

so in mathematical graphemic form that expression turns to:  
mArA = mB(r - rA) (eq num 1? or letter a? )

we may leave r sub a alone passing the mass of star m to the other side of the equation. Keeping in mind that for our purposes the total mass of the system is Total = m sub a plus m sub b or in graphemic form

M total = ma+ mb  
substituting we get that r sub a equals

rA = mBr/(mA + mB).   
or rA = mBr/M where M is the total system mass.

If The forces acting on each star are balanced, that is the gravitational force or Fsub g equals the centripetal force or F sub c then in mathematical graphemic form i may write that as:

FG = FC or  
because we have two mases ( two stars) and the gravitational force by one mass over another is defined as the ratio of universal gravitational constant multiplied by product the masses, all that divided by the square of the radius. in graphemic form it is written as equation ? ( nemeth) and G, the universal gravitational constant as defined earlier is negative.  
**F** = -**GmM**/r2 ( nemeth)

but force is also equal to the multiplication of mass by speed divided by then you may equal equation # and eq # for the masses a and b and r a or rb or rsub c. Remember we are using as an example the displayed binary system in the sandi frame. In mathematical graphemic form it will be

F = GmAmB/r2 = mAv2/rA ( nemeth) ( number or letter?)

where v is the orbital speed of star A.(nemeth)

Unless v can be measured or inferred directly from Doppler shift in its spectrum it must be calculated from the period, T ( capital T). then v is equal to 2 multiplied by pi multiplied by r sub a and all of that divided by the period T. Following is the mathematical graphemic form

v = 2πrA/T ( nemeth)  
so substituting this into equation number ? for force gives:  
the gravitational constant multiplied by the ratio of the mass of any of the stars lets say for now mass of star b divided by the square of r is equal to 4 multiplied by pi multiplied by r sub a and all of that divided by the square of the period T. graphemic form below on equation # or letter?

GmB/r2 = 4π2rA/T2 ( nemeth)

so if we then substitute in () we get:

GmB/r2 = 4π2mBr/T2M  
Or  
M= 4π2r3/GT2 (\*\*)  
which can be rewritten as:  
**mA + mB = 4π2r3/GT2** (\*\*\*)  
now (\*\*) is simply an expression of Kepler's 3rd Law; r3/T2 = GM/4π2 (\*\*\*\*)

M = 4π2r3/GT2 (\*\*)  
  
which can be rewritten as:

**mA + mB = 4π2r3/GT2** (\*\*\*)  
  
now (eq?) is simply an expression of Kepler's 3rd Law;  
 r3/T2 = GM/4π2 (\*\*\*\*)

Using equation \*\* or \*\*\*

**Lesson 9: Analysing Pulsar data…is it pulsating?**

You may have heard the term frequency which is measured in Hertz. One hertz is one wave circle per second. In terms of our ears Frequency is a measure of the number of vibrations a sound wave makes per second or perceptually more than a milliseconds or how often the parts of your ear (ear canal, ear drum, hairs on the choclea etc) when a wave passes through the medium. and in fact any sound may be decomposed into into a number of frequencies and/or composing frequencies.

By identifying periodic signals or frequencies in the measurements the scientists are able to determine properties of stellar systems like neutron stars.

The ear performs something analog but not as limited as something called a fourier transform and curiously enough astronomers perform fourier transforms to analyse their data. A fourier transform changes measurements acquired over time or in the time domain to the frequency domain. The mathematical fourier transform is very limited due to leakage, the nyquist criteria and one has to assume the data to be piecewise stationary.

Astronomers use Fourier transform to display the measurements as a large number of periodic components, each with a different period and a different strength. Very strong components may appear in data where there is a periodicity present. Astronomers then corroborate if this salient features are of importance.

We need to be careful as to what we identify as a real signal. Signals may be almost indistinguishable in the noise. Noise is the not useful part of the data. A signal does not has to be many times stronger than it would be in a random data set to be taken seriously but it has to be confirmed to be real and not from systemic origins. Like our ears that transform a traveling wave into the frequency domain a Fourier transform decomposes the wave into an infinite number of sine waves but not with the same resolution or sensitivity so when using fourier you have to be careful on how many data points you use not to cause leakage on your data. In the frequency domain, the ear enriches the fourier or any spectral analysis as one can describe sounds in terms of the several frequency components that compose the sound.

You may want to run the BlackHole.exe or BlackHole.sh experiences included in this book for you to practice bi-sensorially to identify is there is any signal in the data. this kind of analysis is used to identity glitches or events that are weak in the data and unpercevable by the human eye when the noise is hindering the data.

Now lets time the period of a pulsating star data?

**we will use a technique called Epoch folding**

This is done by choosing a range of periods, and "folding" the data at those periods.Listen or plot, ( on the cardis or on paper) data corresponding to ???????

As an example, lets say that an astronomer has one reading per second for 500 seconds of an object. The astronomer listens, touch or looks at the plotted data and by exploring at the changes in the light intensity, the astronomer suspects that the object has a period of 25 seconds, so she will "fold the data on a period of 25 seconds." how is that done? To do this, she would start with the first 25 points, and then add the second 25 points (points 26-50) to the first 25. she will get a result and will add it to a brand new new table of intensity over frequency or intervals. Then at this point you may make a table with one column called intensity and another called frequency. This may be determine by how many intervals or octaves they tones, rhythms or beats ( depending on your mapping) are separated i.e one octave, third …fifth. fourth …Now add the third set of 25 points, and so on, until she reaches the end of the data set. at the end we will hear the resultant sound and compare it with the first period. Plot and hear simultaneously the new intervals. We will hear the result and compare with the original. If the period of the source is not close to the 25 seconds first suspected , then when you hear the data sets together the sounds of. the peaks will cancel out meaning the times where the signal is high will cancel out with times where the signal is low in each of the 25 "bins", and the resulting sound of the plot of the light curve curve will not have anything to identify as a new period. as you heard in the experience of the BlackHole signal we need to that identification carefully. If, however, 25 the result will be a very sound variant resultant epoch light curve folded . Before you celebrate finding any new periods we must assess how significant the resulting light curve is. This is generally done by looking at the spread of values, or errors, in the typical bin, and comparing how much higher the high bins are than the standard error.[ref AAVSO]

The data attached for sonification and the visual and tactile illustration below show the process of epoch folding for CH cygny using data from the Chandra X-ray observatory.

In the light curve for pulsar ? i do not know which one to use and i have no data….There are spikes in the intensity that seem to repeat at regular intervals. You may do that by counting , keeping tempos etc you may only need to remember to change it to the units in the chart. how long is the period ?

Listen to the light curve ( we should give them one with periods i have ex-hydra). There are periods where the intensity and decreases in a kind of similar fishion that seem to repeat at regular intervals.

We are giving you a separate sheet with another xray data for a pulsar to plot either on the cardis, xSonify using different timbres or on the sonoUno using the high pitches sounds it has. First follow the instructions on the FFT document to carry the fft using sonoUno or xSonify or GNU octave. Then plot all of them. Plot all the folded chunks , the result of the summation of the plots and the original chunks before adding anything data and also form with the computed bins a new plot and compare the the original to the new one and keep attention to the separation of the intervals. do you notice any changes in the intervals, intensities or in the period you first identified?

**Lesson 10 Determine the frequency at maximum strain amplitude** *f* 􏰅􏰅

from what we have dialogued the gravitational wave frequency at which the waveform has maximum amplitude is a very important value. Using the zero-crossings around a high intensity peak on the chart ( on other charts will be known as the brightest point) we may calculate a frequency value.

If the bodies were orbiting each other we may use that frequency to calculate the orbital angular frequency which is equal to the result of a division: first multiply 2 by Pi and multiply this by the frequency of the gravitational waves and divide it by two. In graphemic form the numbers are

GW max =2π× freq/2.

For the binary system we denote the two masses by lower case *m*1 and lower case *m*2, the total mass by capital *M equals lower case m1 plus lower case m2 (in graphemic form written as M*=*m*1+*m*2),

the reduced mass equals the result of a division which is the result of the multiplication of m1 by m2 divided by the total mass. in graphemic form is written as:

μ = *m*1 *m*2 / *M ( nemeth)*

We define the mass ratio *q as equal to mass 1 divided by mass 2. in mathematical graphemic form:*

*q =*  *m*1 / *m*2

we will assume that *m*1 is bigger or equal than m2

in graphemic form m1≥ *m*2

so that the mass ratio *q is bigger or equal to 1*

*in graphemic form*

*q* ≥ 1.

To describe the gravitational wave emission from a binary system, a useful mass quantity is what astronomers know as the *chirp mass*, M ( denoted here as capital M), related to the masses of the two objects and it is equal to the multiplication of mass one by mass 2 and that result is elevated to the three fifths.

(*m*1 *m*2 )3/5

then the chirp mass is equal to the summation of mass 1 plus mass 2 that result elevated to the one fifth.   
M=(*m*1+*m*2)1/5.

Using Newton’s laws of motion, Newton’s universal law of gravitation, and Einstein’s formula for the gravitational wave luminosity of a system, a formula is derived to relate the frequency and frequency change (or frequency derivative) of emitted gravitational waves to the chirp mass. Then the mass is equal to the

result of a long multiplication which is: the result of the third power of the rate of change over time of the frequency of the gravitational wave, multiplied by the negative eleventh power of the frequency of the gravitational wave , multiplied by the third power of 5 over 96 and all those multiplications elevated to the power of one fifth. In graphemic form it will be:

( my sister and i couldn’t write it)… we tried we couldn’t even find an image.

Then determine from the plot ( in audio, tactile or visual the gravitational wave frequency and the rate of change over time of the gravitational wave frequency, substitute in the equation and calculate the mass. ( i need a donation of data with a chirp) For this we will use the time-frequency plot of the observed gravitational wave strain data from EGO, calculate the frequency change by calculating the slope(the inclination) of tangent lines drawn at points of change on the curve. Identify two points in the graph where for example the curvature of the graph changes. Draw a tangent line to that part of the graph and calculate the slope of the tangent line. That will give you an instantaneous rate of change.

For a binary system we denote the two masses by *m*1 and *m*2, the total mass by *M*=*m*1+*m*2, and the reduced mass by μ = *m*1 *m*2 / *M*. We again define the mass ratio *q* = *m*1 / *m*2 and without loss of generality assume that *m*1 ≥ *m*2 so that *q major or equal to one in graphemic form* ≥ 1. And now we may use the following equation which relates the frequency and the rate of change for the frequency emitted to the mass. We will use the frequency we calculated on that equation ( the next one) to calculate the chirp mass.

Again: but now without us providing the data. Go to the European Gravitational Observatory data base ( i need help to use) gather some strain data: measure the time differences between successive zero-crossings once you have that , estimate the frequency of the gravitational wave using equation # ( it is above) or *f*GW = 1/(2􏰁*t*), without assuming a waveform model. Now elevate all that to the −8/3 and plot the power of these estimated frequencies and based look, listen or look and listen to it. From the behaviour of the oscillations its physical relevance, calculate the masses and if the data you have is indicative of two bodies orbiting each other.

**Lesson 12**

The nuclear black holes in galaxies are believed to be fed with gas accretion triggered by mergers of galaxies. The energy released by the accreting gas during these episodes could release the gas reservoir from the host galaxy and slow or suppress star formation within it. If so and very similar to our dialog at the beginning , nuclear black holes also regulate their own growth by expelling the gas that feeds them. In so doing, they also shape the stellar content of their host galaxy. This may explain the relation between the mass of central black holes in present-day galaxies, the velocity dispersion in an area and the luminosity of the bunch of stars hosting it.

in graphemic form we write that the mass of the black hole is proportional to the fourth power of the velocity of dispersion written

in mathematical form as as: *M*BH proportional to σ⋆4

( the greek letters i expect will be complicated to convey in nemeth code)

or that the mass of the black hole is proportional to the luminosity Lets bring back to subject the viral theorem! This is why it is important to know the whole evolution of the source. The mass of a galaxy scales with its virial velocity as the m*ass being proportional the third power of the viral velocity mathematical graphemic form in nemeht on number ?? or letter ??*

*then* the binding energy of galactic gas is expected to scale as a proportionality where the mass multiplied by the square of the viral velocity is proportional to the fifth power of the viral velocity. This may perhaps be also used to figure out the relation between black hole masses and the properties of the host galaxies.

**Lesson velocity** 13

On earlier chapters we stated that the equation of potential energy and kinetic energy equations equal to each other, then we can relate the kinetic energy a particle gains as it falls to its current distance of R from the center of mass. The quantity, M, is the mass of the gravitating body the particle is falling towards. we can then solve for the speed, V.

( i did not write the equation because square roots are hard to graphemically write and i did not feel like using a one half power, i need help here)…but continuing with the lesson….

lets imagine that a brand new star has a companion no sighted person has ever “seen”. with a very powerful source of X-rays in the sky and through observations astronomers have determined the mass of this companion to be 8.7 times the sun.Also lets say that as black hole, its event horizon radius would be R = 2.8 x 8.7 = 24 km.

How fast, in km/sec, would a will body be when passing through the event horizon?

it will be nice to have an example here of this type ( lets get a plot of ???????? and you should estimate the radius and mass of the object from the plot) i just do not know what to use or describe the chart.. ...i apologise....

plot estimation is done by  
(i) taking the minimum value of R from its plot and  
(ii) considering the maximum value of T from its plot and so

calculate the radius.

**Lesson 14**

Lets sensorially study to an xray light curve. We may listen to the duration of the x-ray bursts to approximately calculate how large an emitting region is, and since the source is a black hole, it gives the approximate diameter of the black hole. From the conversation on degeneracy you may remember that once the condensing object reaches a radius equals to three times the mass of the sun R = 3 M it will collapse to singularity. Then we may relate that radius to the mass of that starting blackHole/. From the chandra X-ray centre we may listen to the the light curve of an xray source using the sonoUno or the xsonify. ( put a link for people to learn to use it). The x axis is time in days and the y axis is xray brightness ( intensity of light on xray). Using beats, tempos or counting notes you may Identify lengths of the periods from increasing to decreasing tones that may be similar in their periods. You may also want to copy the plot into the cardis foamboard. and explore the duration in a tactile way. If you identify more than one period just calculate an average duration of the periods you identified what is the duration?

using the velocity of light 3.0 x 10^8 km/s and the duration you estimated you may estimate the size of the emitting region, assuming it is circular, (you have a width), calculate the radius and then you may substitute and get the mass of the object!