DETERMINATION OF TEMPERATURE OF STARS IN M12 CLUSTER AND HENCE VERIFY WEIN'S CONSTANT

BACHELOR OF SCIENCE
PHYSICS (2017-2020)
UNDER
FAROOK COLLEGE (AUTONOMOUS)

Submitted By
VASEEM SHUHAIB(FKARSPH047)
ZAINA SHAHLA(FKARSPH048)
SELVA (FKARSPH036)
SUMMAYA C P(FKARSPH045)
AMAL MOHANDAS(FKARSPH005)

UNDER THE GUIDENCE OF
NASEEF MOHAMMED PN
(ASSISTANT PROFESSOR, DEPARTMENT OF PHYSICS)

ORA ET LABORA

FAROOK COLLEGE
PG & RESEARCH DEPARTMENT OF PHYSICS
FAROOK COLLEGE (PO),CALICUT

CERTIFICATE OF GUIDE

This is to certify that the project work entitled**"Determination of Temperature of stars in M12 cluster and hence verify Wein's constant"** is done by Vaseem shuhaib, Amal Mohandas, Selva, Summaya c p , Zaina shahla , sixth semester BSc. physics students of Farook college under my guidance for the partial fulfillment of under graduate programme during the year 2017-2020.

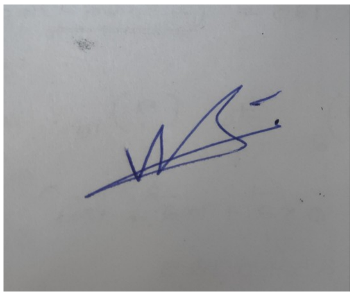
NASEEF MOHAMMED P N

Assistant Professor

DECLARATION

I vaseem shuaib k hereby declare that project entitled “**Determination of Temperature of stars of M12 cluster and hence verify Wein’s constant**” is done by Vaseem shuhaib , Amal Mohandas , Selva, Summaya c p , Zaina shahla ,sixth semester BSC physics students of farook college under the valuable guidance of Mr. Naseef mohammed P N (assistant professor, department of physics,farookcollege). This project report does not form a part of my other degree of Calicut University of any other university.

Vaseem shuaib k



08/06/2020

ACKNOWLEDGMENT

We express our everlasting gratitude to professer K M Naseer,principal of farook college permitting us to do theproject.

We kindly thank P A Subha,head of department , for her guidance forsupport.

We express our sincere gratitude to our project guide Mr. Naseef mohammed P N who guided us throughout the project and gave us a lot of motivation.

Our special thanks to all teachers and lab assistants and classmates for their sincere motivation and support.

Vaseem shuhaib

Amal Mohandas

Selva

Summaya c p

Zaina shahla

CONTENT

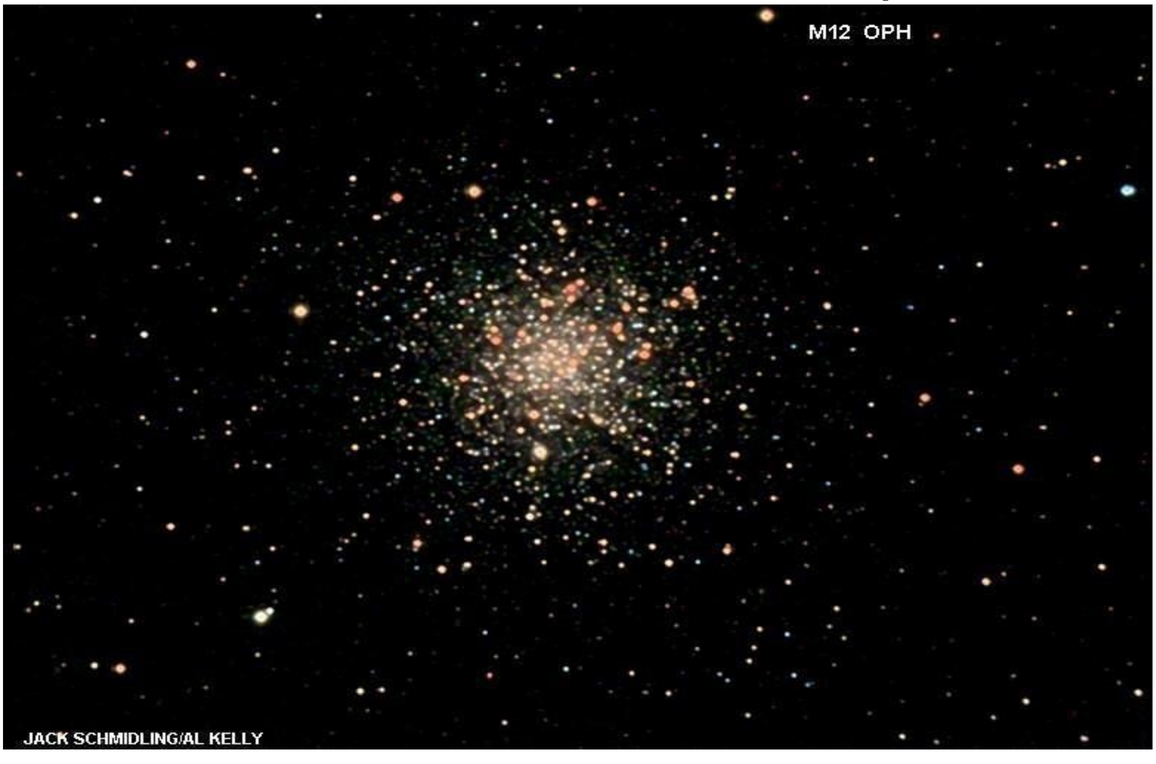
INTRODUCTION

Astronomy is the study of the universe beyond the earth's atmosphere.
The main branches are astronomy, celestial mechanics, and astrophysics.

Astrophysics is the branch of astronomy concerned with the physical processes associated with the celestial bodies and the intervening regions of space .It deals principally with the energy and the evolution of the system.

The project is related to astrophysics. Here we are determining the temperature of different stars in the M12 cluster to verify the Wien's constant.

M12 cluster (messier12) is a globular cluster in constellation of Ophiuchus, discovered by Charles messier located roughly 3 degree in the sky from the cluster M10 and 5.6 degree from the star LAMBDA OPHIUCHI,M12 is about 15,700 light-years (4,800 parsecs from earth and has spatial diameter of about 75 light-years (Right ascention **16' 47'' 14.18'''** ,Declination **-01**° **56' 54.7'')**



For the collection of data and analysis, IRAF (image reduction and analyzing facility) has been employed along with other software’s like **ds9** etc.

IRAF is a collection of software written at the national optical astronomy observatory geared towards the reduction of astronomical images in pixel form . This is primarily data taken from imaging array detectors such as CCDs it is available for all major operating systems . Functionality available in IRAF includes the calibration of fluxes and positions of astronomical objects while an image , compaction for sensitivity variations between detector pixels, combination of multiple images or measurement of the red shift of absorption or emission lines in spectrum .

SExtractor is a program that builds a catalogue of objects from an astronomical image. Although it is particularly oriented towards reduction of large scale galaxy-survey data, it can perform reasonably well on moderately crowded star fields.

SAOImage DS9 is an astronomical imaging and data visualizing application. DS9 supports FITS images and binary tables, multiple frame buffers, region manipulation, and many scale algorithms and color maps. It provides an easy communication with external analysis tasks and is highly configurable and extensible.

There are many different types of stars in the universe, from proto stars to red supergiant. They can be categorized according to their mass and temperature. Stars are also classified by their spectra (the elements that they absorb). Along with their brightness (apparent magnitude), the spectral class of a star can tell astronomers a lot about it. There are seven main types of stars. In order of decreasing temperature, O, B, A, F, G, K, and M. O and B are uncommon, very hot and bright. M stars are more common, cooler and dim.

Stars are astronomical objects consisting of a luminous spheroid of plasma held together by its own gravity. They emit thermal radiations in continues spectrum according to their temperature. A star shines due to thermonuclear fusion of hydrogen into helium in its core releasing energy that trances the star’s interior and then radiates into outer space.

Radiation is also produced by the acceleration or deceleration of a charged particle after passing through the electric and magnetic fields of a nucleus.

A star approximates the behaviors of a blackbody radiator. As a black body gets hotter, its color changes, if it were hot enough, a blackbody emits most of its energy in ultraviolet region. The color of a star is primarily a function of effective temperature. The color that we see is usually the additive combination of emission from each wavelength. Hot stars appear blue because most energy is emitted in the blue part of spectrum. There is a little emission in the blue part for cool stars. They become red color.

Magnitude is a number that measures the brightness of a star or galaxy. In magnitude, higher numbers correspond to fainter objects, lower number to brighter objects, the very brighter objects have negative magnitude. In practice astronomers measure the amount of light or flux in a restricted wavelength band. This can be done by letting the incoming beams of light go through a filter. The filters work by blocking out light at all wavelengths except those around the wavelength they are designed to see. Rather than just have one apparent magnitude , m measured across the entire visible spectrum we can use a filter that only allows light in blue part of the spectrum. We can use a filter that approximate the eye’s visual response , which peaks in the yellow green part of the spectrum. When a star is said to have certain magnitudes, the color that magnitude refers to must be specified.

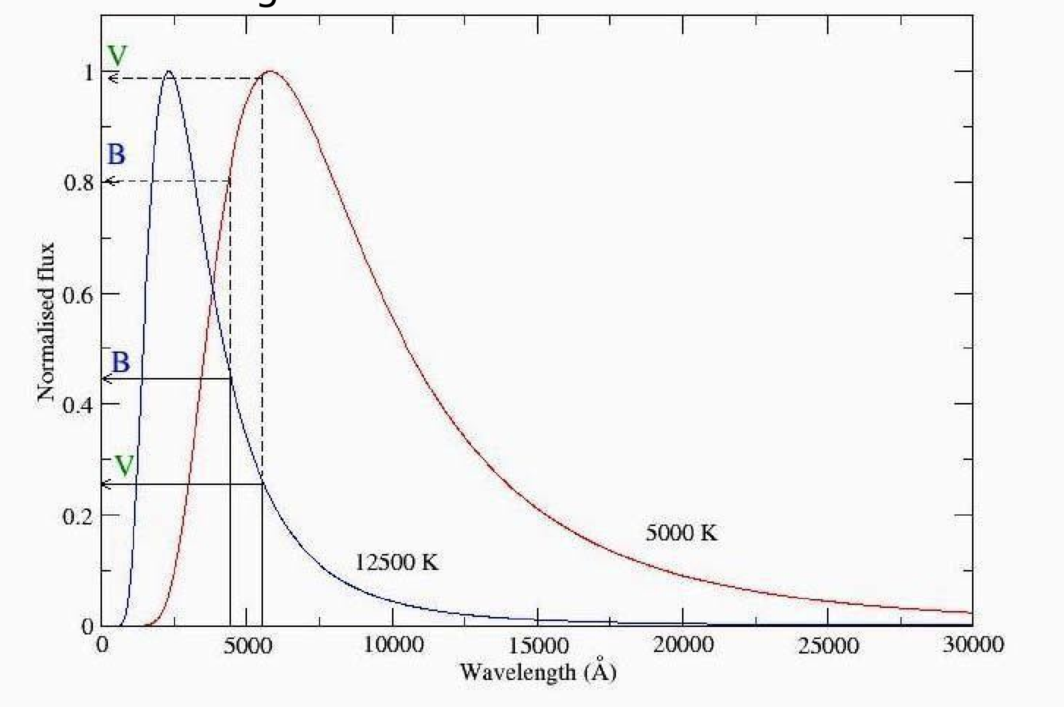
Color is defined as the difference between the magnitude of a star in two different filters. The physical property that magnitudes actually measures is radiant flux-the amount of light that arrives in a given area on earth in a given time. It is a logarithmic quantity, a magnitude $m=4$ star emits 2.51 times light as a magnitude $m=5$ stars B-V is the difference between a stars blue magnitude and the same stars green magnitude. Magnitude is defined as

m = -2.5 log (fx\f vega)

where fx is observed flux in band x and F vega is the flux of stars , in constellation of lyra which is used as reference in the magnitude system [Vega has the arbitrary definition of zero magnitude at all wavelength]. A graph of the amount of energy insides the body per unit volume and per unit frequency interval plotted versus frequency is called blackbody curve. These have quite a complex shape. The intensity (the flux) at all wavelength increases as the temperature of the curve increases rapidly when temperature increases (Stefan Boltzmann law)

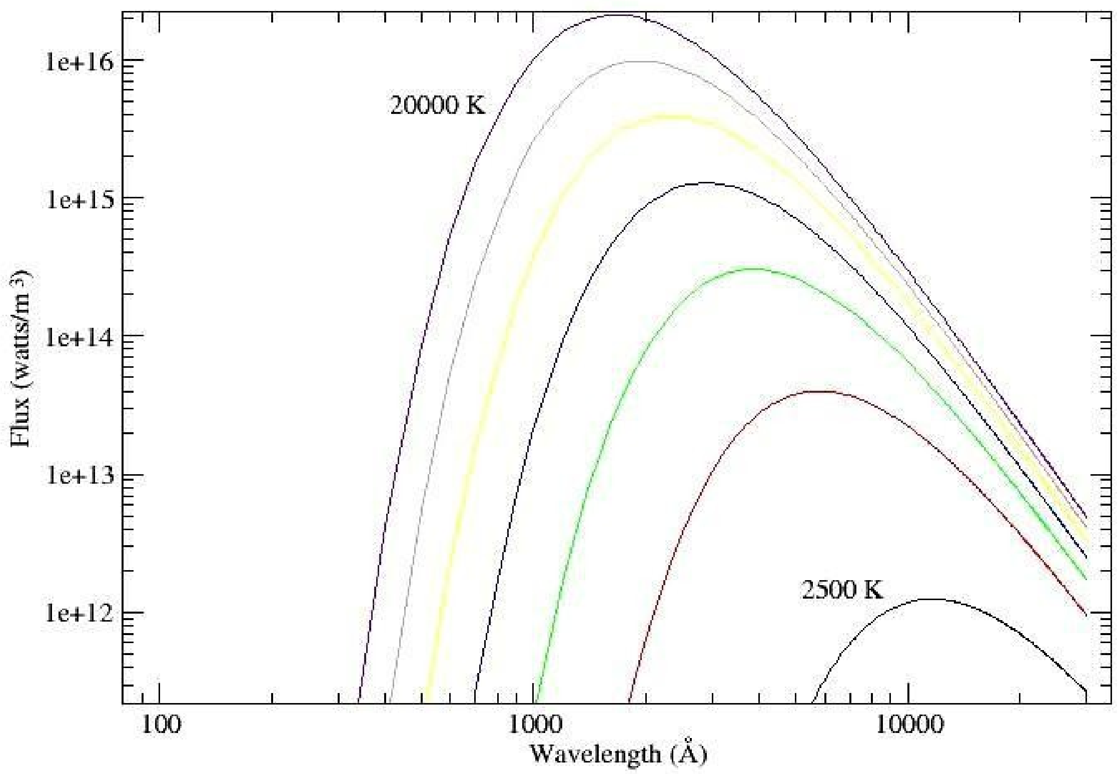
To create a program that obtains the blackbody energy distribution curve for a given temperature we have to define a range of wavelength (in this we took 100amstrong -30000amstrong) in one column on the right column the radiated power of a blackbody using the power density planks law is calculated.

The diagram below shows two curves produced by two different stars [one with an effective temp of 12,500 k and other one with 5,000 k . In the visible part of spectrum the curve is sloping down to the right for 12,500 k stars whilst it slopes up for the cooler star the two black lines represent the peak wavelengths of the B and V filters



The blue curve represents the 12,500 k stars. It emits more energy in the B waveband than in V waveband this means that it is brighter in B than in V therefore its apparent magnitude B will be lower than apparent magnitude V the color index is B-V . it is negative for this stars and positive for 5000k stars [red color]

A stars color can give clues to an important property of star its average temperature. Physicists have found every object in the universe emits thermal radiation so ofcourse, thermal radiation is emitted by stars. The curve shows that, the hotter stars gives off more thermal radiation. The curve also shows that the peak wavelength of the thermal radiation moves to shorter wave lengths as the temperature increases.



Wien’s law is an important formula that allows as to determine the surface temp of a star. It state that the black body radiation curve for different temp , will peak at different wavelength that are inversely proportional to the temperature the shift of the peak is a direct consequence of the plank radiation law.

According to Wien’s displacement law,

$$\lambda_{max} = b / T$$

$$\lambda_{peak} T = 2.87 \times \mathbf{10^{-3}}\ \mathbf{mk}$$

INSTRUMENTATION

Fits image of m12 star cluster

We are analyzing fits image file of M12 cluster **Flexible Image Transport System (FITS)** is an open standard defining a digital file format useful for storage, transmission and processing of data: formatted as multi-dimensional arrays (for example a 2D image), or tables. FITS is the most commonly used digital file format in astronomy. The FITS standard was designed specifically for astronomical data, and includes provisions such as describing photometric and spatial calibration information, together with image origin metadata.

IRAF

IRAF (Image Reduction and Analysis Facility) is a collection of software written at the National Optical Astronomy Observatory (NOAO) geared towards the reduction of astronomical images in pixel array form. This is primarily data taken from imaging array detectors such as CCDs. It is available for all major operating systems for mainframes and desktop computers. Although written for UNIX-like operating systems, use on Microsoft Windows is made possible by Cygwin. It is primarily used on Linux distributions, with a growing share of Mac OS X users.

IRAF commands (known as tasks) are organized into package structures. Additional packages may be added to IRAF. Packages may contain other packages. There are many packages available by NOAO and external developers often focusing on a particular branch of research or facility.

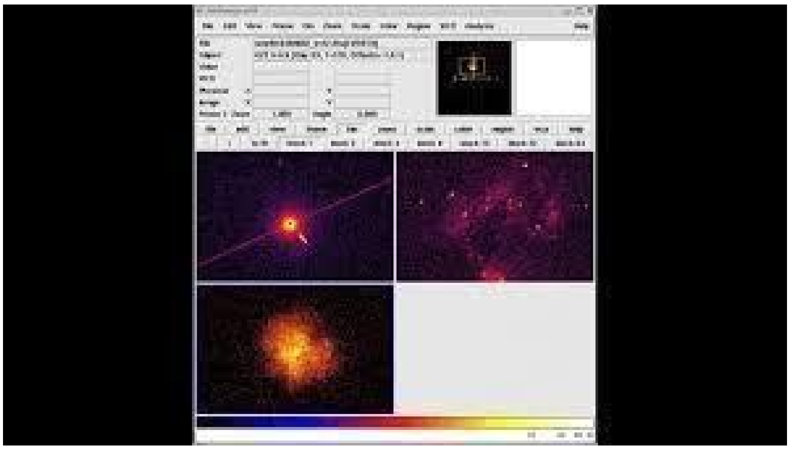
Functionality available in IRAF includes the calibration of the fluxes and positions of astronomical objects within an image, compensation for sensitivity variations between detector pixels, combination of multiple images or measurement of the red shifts of absorption or emission lines in a spectrum.

A full IRAF working environment usually requires two other applications: an extended xterm window with a graphics windows (called xgterm and distributed in a separate X11-IRAF package by NOAO) and an image display program referred to as an "image server". The two most popular image servers are ***ds9*** (by SAO) and ***ximtool*** (NOAO).

Ds9

DS9 is one of the most commonly-used FITS image viewing programs,**DS9** is an astronomical imaging and data visualization application. DS9 supports FITS images and

binary tables, multiple frame buffers, region manipulation, and many scale algorithms and colormaps. It is actively developed at the Smithsonian Astrophysical Observatory and is released under an open-source licence (GPL v3). It provides for easy communication with external analysis tasks and is highly configurable and extensible.



ANALYSING M12 CLUSTER

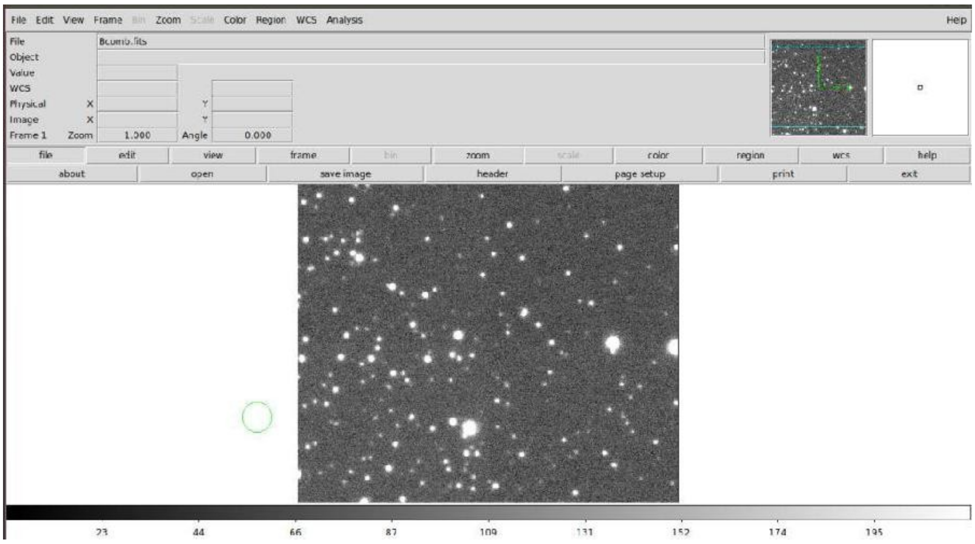
M12 cluster is a magnitude +7.2 globular cluster in Ophiuchus constellation that was discovered by Charles messier on may 30,1764 . He wan unable to resolve the cluster, describing it as “nebula will about” stars

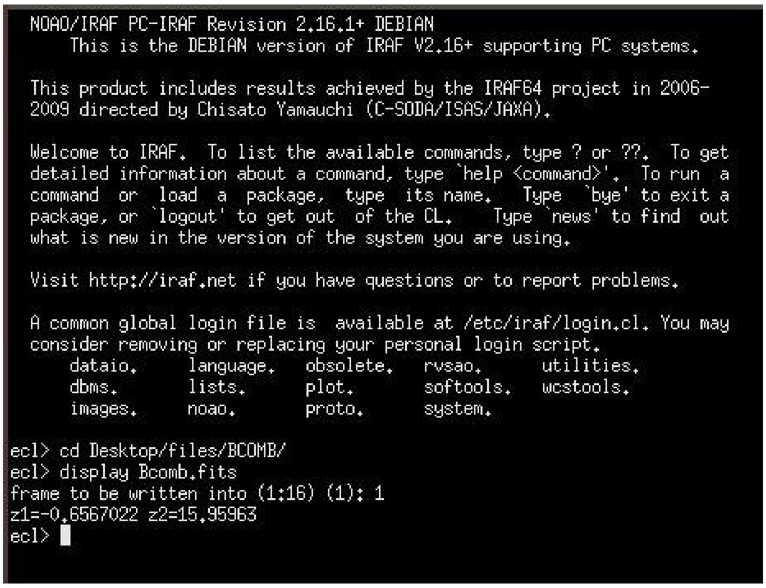
M12 is located in a barrel area of sky that devoid of bright stars and therefore finding it is a tedious task it is located about 8 degrees northeast of the stars. The time of the year to observe M12 during the month of May, June and July.

Analysis using IRAF:

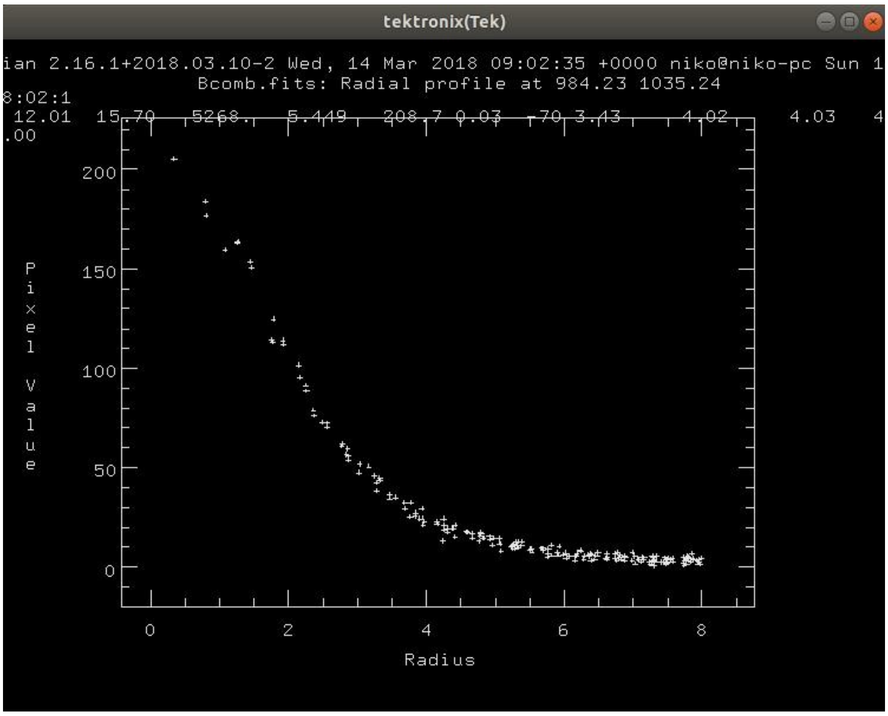
Starting IRAF and ds9, display the image using the command

display ‘file name’.fits



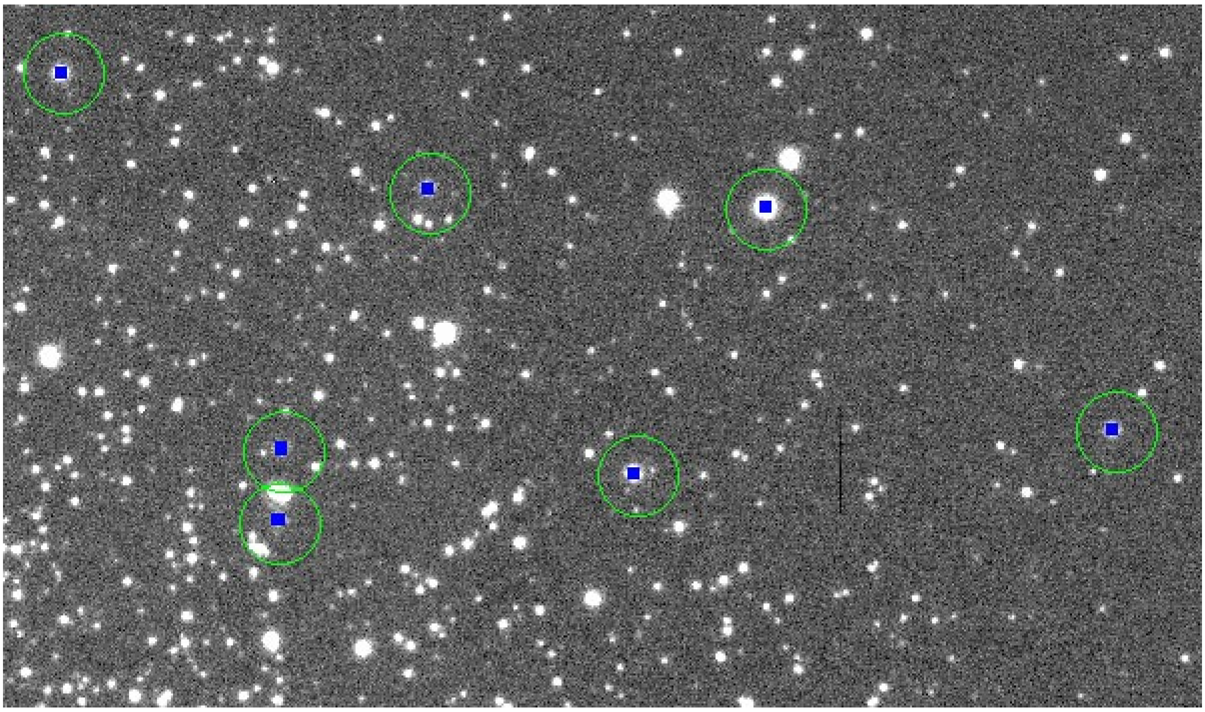


Run imexamine and move the cursor the image display. By pressing ‘r’ where get radial profile .The last three numbers inside the yellow at the top of figure are the FWHM (the full width at half maximum).



The graph represents the radial photons erratic profile of stars. The vertical axis is graduated in relative intensity and the horizontal axis represents the distance in pixels relative to geometrical centre of the star the FWHM of this star is about 4.3 pixels

Like this about 12 stars are selected from the cluster, those having FWHM values between 3.7 and 4.2 other condition Was that there should not be



any stars near the selected one so that we could make sure that the magnitude obtained is absolutely due to the selected one's brightness.

Next step is to get the b and v values to obtain the magnitude.

To obtain the instrumental magnitude of the selected stars we use the sextractor program to get catalogue informations from the fits image file of M12 cluster. By this we get the necessary information.

1)	1291	1126.9856	680.7761	3.39	9.085204	9.4784	10.0221	9.6666	9.5806	0.0047	0.0040	0.0038	0.0037	44406.29
2)	1201	928.3713	637.9510	3.39	9.387627	10.2845	10.8332	10.4769	10.3911	0.0068	0.0058	0.0056	0.0055	21135.34
4)	1551	857.7227	810.3662	3.52	9.179371	10.5871	11.1445	10.7763	10.6894	0.0079	0.0067	0.0065	0.0063	15993.77
6)	1448	1162.2114	788.8005	3.53	8.842205	9.2221	9.7973	9.4231	9.3350	0.0042	0.0036	0.0034	0.0033	56229.5
8)	1583	1575.3396	826.3624	3.30	8.523938	10.1067	10.6508	10.2886	10.2055	0.0063	0.0053	0.0051	0.0050	24895.85
9)	804	1699.2620	446.5905	3.42	8.581152	9.9116	10.4587	10.0976	10.0134	0.0057	0.0049	0.0047	0.0046	29796.1
10)	1031	1996.6907	556.8040	3.27	8.485427	9.5083	10.0534	9.6970	9.6097	0.0048	0.0040	0.0039	0.0038	43197.84
11)	1889	983.9466	1034.8325	3.39	8.946307	10.4760	11.0245	10.6643	10.5799	0.0075	0.0063	0.0061	0.0060	17717.67
12)	1889	983.9466	1034.8325	3.39	8.946307	10.4760	11.0245	10.6643	10.5799	0.0075	0.0063	0.0061	0.0060	17717.67
14)	2224	667.9050	1134.5166	3.47	9.124159	9.3045	9.8735	9.4996	9.4135	0.0044	0.0037	0.0036	0.0034	52117.29
15)	1896	1297.2844	1059.9633	3.59	8.913666	8.4137	8.9664	8.6069	8.5215	0.0029	0.0024	0.0023	0.0022	118389.3
5)	1435	855.5768	749.3757	3.47	9.326419	10.4061	10.9729	10.6053	10.5190	0.0073	0.0062	0.0060	0.0058	18896.13

1)701	1113.8186	502.3367	4.04	5.540171	9.9099	10.6917	10.2400	10.1129	0.0064	0.0052	0.0049	0.0046	29842.31
2)487	1317.4180	332.3423	4.02	5.416969	12.0801	12.8437	12.3839	12.2510	0.0175	0.0144	0.0137	0.0135	4043.657
3)786	1997.0234	557.3799	4.21	5.18705	11.0636	11.8862	11.4129	11.2702	0.0111	0.0090	0.0085	0.0080	10312.16
4)637	1699.5612	447.0864	4.12	5.242332	11.4250	12.2230	11.7566	11.6201	0.0131	0.0106	0.0100	0.0097	7392.531
5)1036	1575.6571	826.8356	4.06	5.109104	11.6345	12.4341	11.9753	11.8361	0.0144	0.0118	0.0112	0.0108	6095.43
6)766	1350.5223	537.7682	4.20	5.33264	11.6779	12.5176	12.0279	11.8851	0.0150	0.0121	0.0114	0.0110	5856.587
7)1001	1162.5586	789.4236	3.97	5.288853	10.8552	11.6349	11.1860	11.0540	0.0099	0.0081	0.0077	0.0072	12494.63
8)979	855.8579	749.7510	3.98	5.794224	11.9394	12.7335	12.2845	12.1511	0.0166	0.0137	0.0130	0.0130	4603.064
9)1025	857.9691	810.7676	4.15	5.723984	12.1408	12.9149	12.4535	12.3224	0.0181	0.0149	0.0142	0.0141	3823.634
10)803	1136.3346	568.3832	4.00	5.461376	12.4053	13.1679	12.7157	12.5830	0.0205	0.0170	0.0162	0.0161	2996.908
11)876	928.6340	638.3688	4.00	5.798384	10.9141	11.6989	11.2463	11.1125	0.0102	0.0083	0.0079	0.0075	11835.22
12)920	1127.2557	681.1760	3.93	5.385723	11.0637	11.8316	11.3874	11.2572	0.0109	0.0089	0.0084	0.0080	10311.07

Magnitude aperture values are noted and charted down and used for further equations [equation of temperature]

CALCULATING TEMPRATURE

How do we determine the surface temperature of stars? Here we are saying about the determination of stellar temperature

That the stars look a little bit redder than the sum so its surface temperature must be less than the sum so its surface temperature must be less than 5800k is a ultra-cheap trick. Disperse the light from a star ("take a spectrum") find the wavelength at which you have most radiation, then apply wein's law. Wein's law let as quantify the colour-temprature relationship but wein's law gives temperature for objects with plank like spectra stars doesn't have specta because of the absorption line, flux redistribution and other complications like that it's know as the cheap trick

To the extent the stellar spectra look like blackbodies, the temperature of a stars can also be measured amazingly accurately bt recording the brightness in two filters

To get stellar temperature:

1) Measure the brightness of a star through two filters and compare the ratio of red to blue lights.
2) Compare to the spectra of computer models of stellar spectra of different temperature and develop accurate colour-temprature relationship.

In this project we are calculating the temperature of stars by using b-band (blue band) and v-bands (violet band) blue and violet band respectively by analysing the M12 cluster in IRAF app by ds9 we get two images of b-band (blue) and v-band(violet) and we separately analyse the bands in ds9 and select the stars which we needed in the procedure of selecting the stars . we have made a condition of its full width hafe maximum in a range 3.7 to 4.2 and select the number of stars which obeys the condition by analysing the stars in ds9. First of all we take the b-band image and analyse the stars and we get the corresponding b-magnitude and then we take the image of v-band and analyse the stars and we get the corresponding v-magnitudes. We want the colour index and for the colour index we are subtracting the b-magnitudes from the v-magnitudes (b-v) and we get the color index. Substitude the color index to the corresponding equation that we have to determine the temperature that we get from the reference

$$T = 4600\,\mathrm{K}\left(\frac{1}{0.92(B-V)+1.7} + \frac{1}{0.92(B-V)+0.62}\right).$$

Thus we obtain the temperature of the corresponding stars that we analyse **Black body** radiation is the thermal electromagnetic radiation within or surrounding a body in thermodynamics equilibrium with its environment, emitted by a black body which is an idealized opaque, no. Reflective body. It has a specific spectrum of wave length, inversely related to intensity that depend only on body’s temperature which is assumed for sake of calculation and theory to be uniform and constant as temperature decreases the peak of black body radiation curve mover to lower intensities and longer wavelength.

DETERMINATION OF WAVELENGTH

A black body at room temperature appears black as most of energy is radiated in Infrared spectrum and cannot be precise by humans eye when it becomes little hotter it appears dull red

In Astronomy objects such as stars are frequently regarded as Black bodies through this is often a poor approximation

Wien's displacement law is the law which states that the frequency of peak of emission (f_{max}) increases linearly with Absolute Temperature (T) conversely temperature of body increases the wavelength at emission peak decreases

Planck's law describe spectral density of electromagnetic radiation emitted by a black body in thermal equilibrium at a given temperature when there is no heat for matters or energy between body its environment

The wavelength of a wave is distance requires to complete one oscillation in Astronomy we often referred to wavelength of given spectral Line or other form of electromagnetic radiation the wavelength of light is related to its frequency of oscillation and velocity.

Flux is total amount of energy that crosses a unit area per unit time flux is measured in joules per square meter per second(j/m^2/s) watts per square meter(w/m^2) the flux of an astronomical source depends on luminosity of object and its distance from Earth

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{kT\lambda}}-1}$$

Taking the range of wavelength from 100amstrong to 30000amstrong with temperature of selective 10 stars by substituting the wavelength temperature and other values in the above equation with

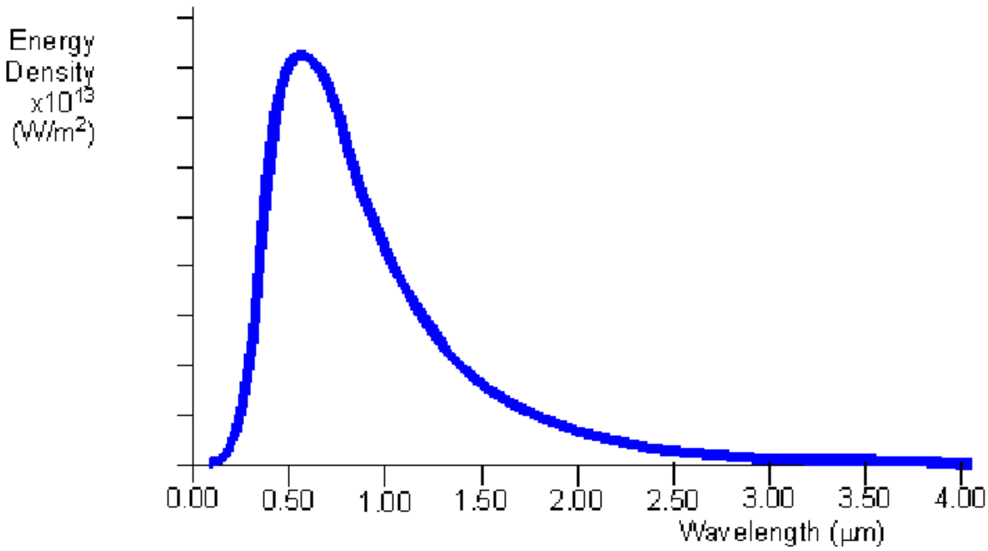
$h=6.626\times10^{-34}$ Js

$K_B=1.381\times10^{-23}$ J/K

$C=2.998\times10^{8}$ m/s

Flux is in units of w/m^3

Using fraction wavelength the black body curvers can be drawn.



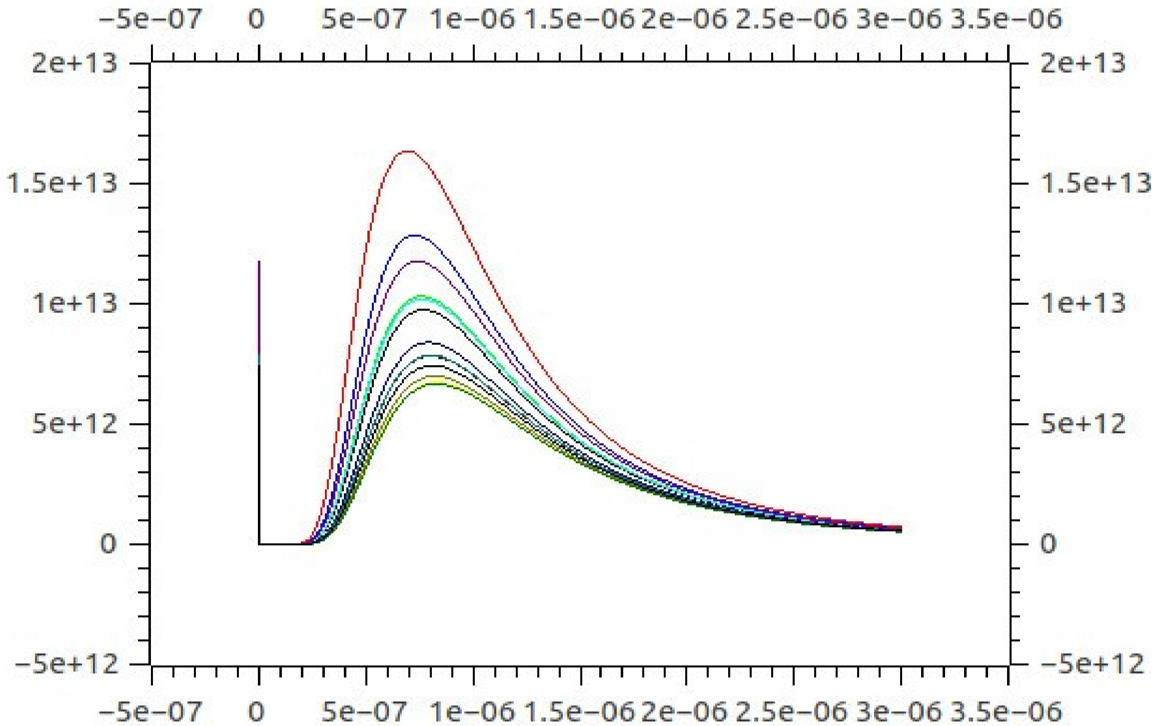
WIEN'S CONSTANT

Wein's law also called Wein's displacement law, relationship between the blackbody and the wavelength of which it emits most of the light. It is named after German physicist Wilhelm Wien, who received the Nobel prize for physics in 1911 for discovering this law.

Wein's law tells us that objects of different temperatures emit specta which emit peak at different wavelengths.For a black body the radiative energy 'dw' per wavelength interval 'dλ' has a maximum value at certain wavelength λm(peak wavelength). At higher temperature λm shifts towards lower wavelength region hence they appear to be bluer. The product of λmT is an absolute constant , termed as Wein's constant.

$$\lambda_m T = \text{constant} \quad \text{------ (1).}$$

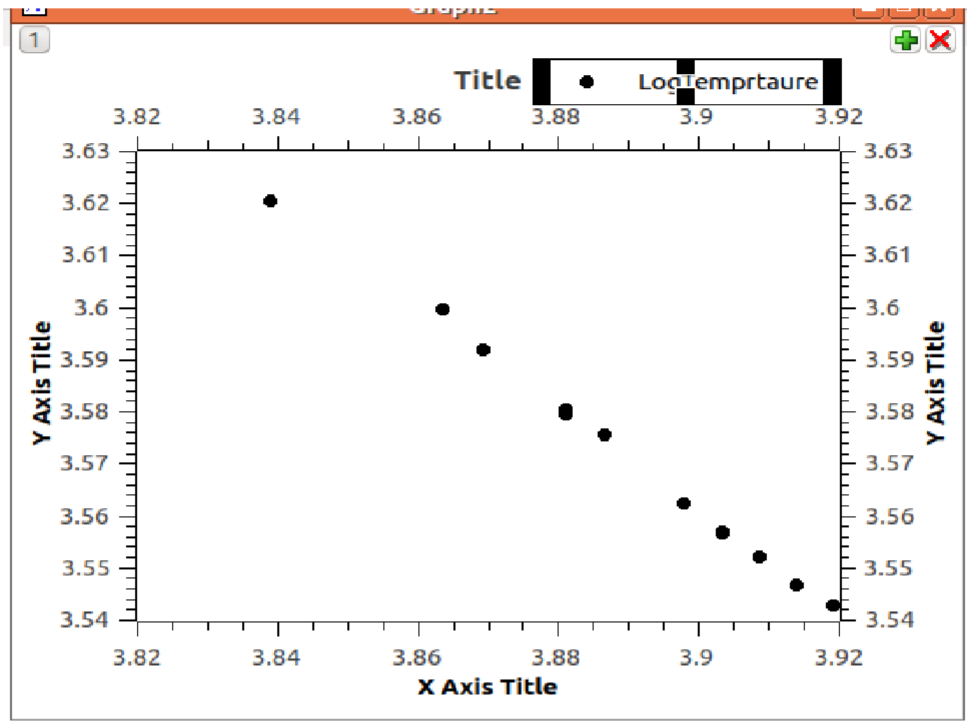
Black body curve of slected stars



(temperature on x-axis, flux density on y-axis)

In our project we use radiations in the range of 100-30000 amstrong from the stars of M12 cluster. Using the blackbody curve we obtained , found out the wavelength at which the flux is maximum. Then created a straight line graph of temperature and the λ peaks using logarithmic scale(temperature on x-axis & peak wavelenght on y-axis) with the help of QTi plot.

Logwavelenght[X]	LogTemprtaure[Y]
3.908485018879	3.552308846551
3.903089986992	3.55715667537
3.903089986992	3.556765402672
3.869231719731	3.592149752346
3.89762709129	3.562674597369
3.913813852384	3.547024866025
3.903089986992	3.556912085618
3.880813592281	3.579609481035
3.86332286012	3.599783037565
3.880813592281	3.580628163864
3.838849090737	3.620798379341
3.886490725172	3.575748164258
3.919078092376	3.542988403261



RESULT AND CONCLUSION

from the above graph

Using the equation y=mx+c

$\log(T_k) = 7.4721 - 1.002 \log(\lambda_{peak}$ Å)

λ_{peak} T = 10^7.4721 / 1.002 = 29595949 Å K

λ_{peak}T = 2.95*10^-3 mk.

Which is nearly equal to the wein's constant in unit of the international system

2.871*10^-3 mK

It's SI unit is metre - Kelvin

The temperature of different stars in M12 cluster is determined using Morgan Keenan system and their spectra are plotted. Hence verified Wien's constant.

Classification Of Temperature

G	H	I
TEMPERATURE	star type	star class
3567.04712188114	K	ii
3607.08748252358	K	ii
3491.3099269129	M	iii
3603.83918136313	K	ii
3909.75687819039	K	ii
3653.20966006719	K	ii
3523.91047015781	K	ii
3605.05658350185	K	ii
3798.47682476719	K	ii
3979.08336045463	K	ii
3807.39700432494	K	ii
4014.9711064143	K	ii
3764.85421858667	K	ii

Equation of flux

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{kT\lambda}} - 1}$$

Equation of temperature,

$$T = 4600\,\mathrm{K}\left(\frac{1}{0.92(B-V)+1.7} + \frac{1}{0.92(B-V)+0.62}\right).$$

wiens law graph

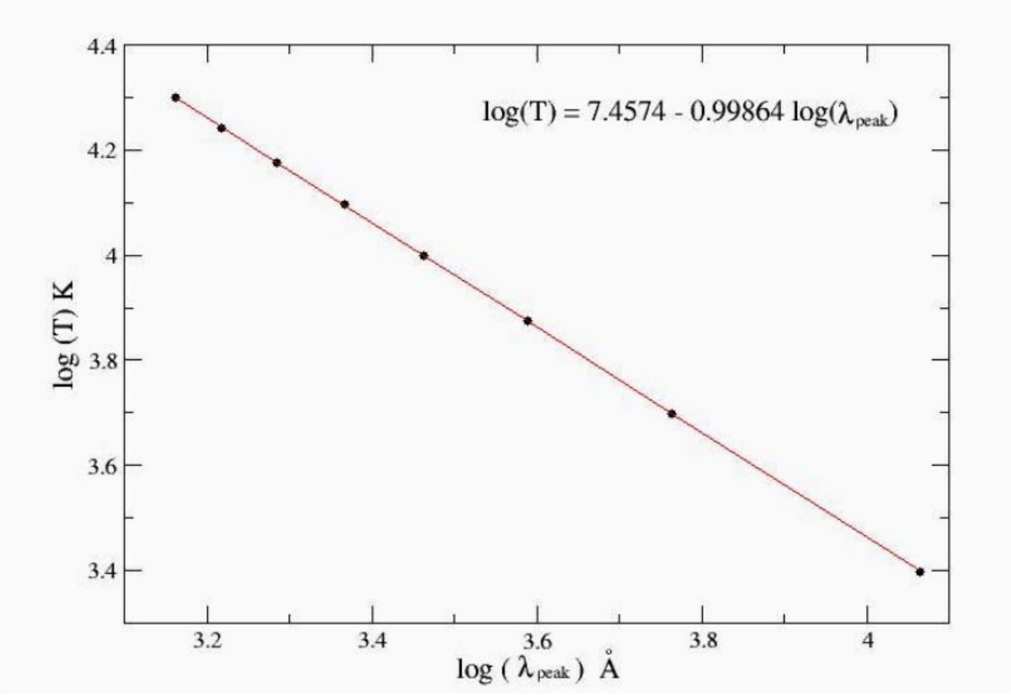
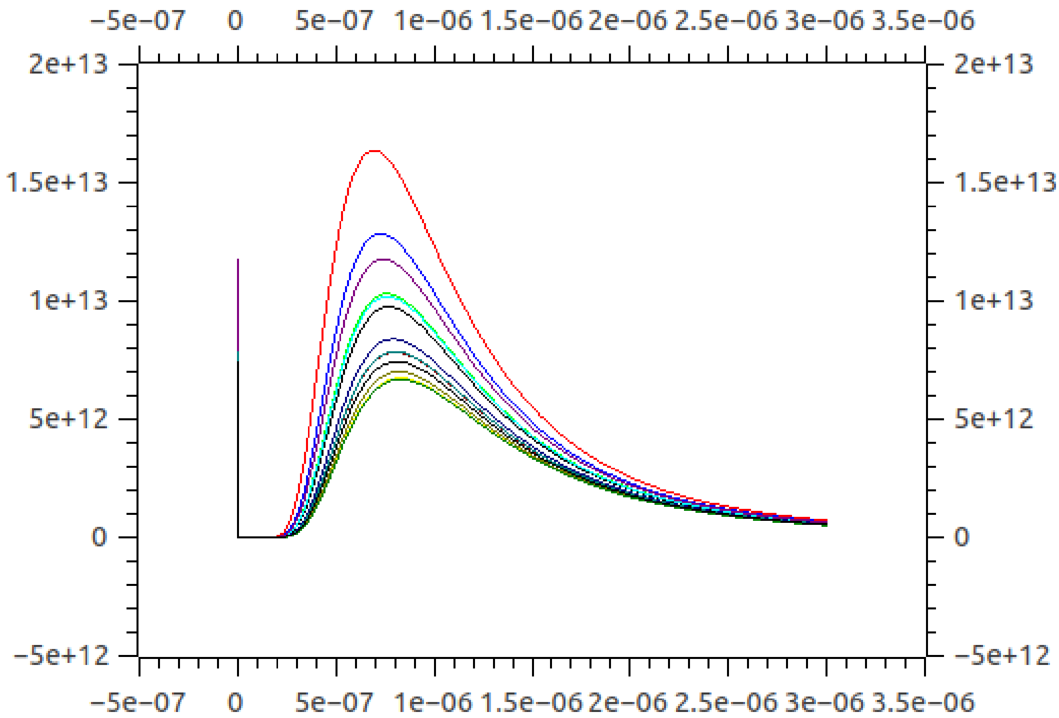


Fig. 8. Temperature as a function of the peak wavelength.

black body curve



(flux density on y-axis, temperature on x-axis)

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