EFFECTS OF EARTH'S ATMOSPHERE ON ASTRONOMICAL OBSERVATION

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A Thesis Submitted to

The Department of Physics

PRESENTED IN FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE
JIMMA UNIVERSITY
JIMMA, ETHIOPIA
FEBRUARY 2020

JIMMA UNIVERSITY
DEPARTMENT OF
PHYSICS

This is to certify that the thesis prepared by **Abate H/Yesus** Graduate Studies entitled " **Effects of Earth's Atmosphere on Astronomical Observation**" in fulfillment of the requirements for the degree of **Master of Science** complies with the regulations of the University and meets the accepted standards with respect to originality and quality. .

Dated: February 2020

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JIMMA UNIVERSITY

Date: **February 2020**

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Title: **Effects of Earth's Atmosphere on Astronomical Observation**

Department: **Physics**

Degree: **M.Sc.** Convocation: **February** Year: **2020**

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Abstract

Currently, the science of astronomy for the study of origins and evolutions is advancing both theoretically and observationally. However, there are a number of works for further developments. For example, the data extracted on earth is highly extinct due to stellar winds, background radiations and planetary atmospheres. In this work we did on the effect of atmospheric extinction on astronomical photometry and spectroscopy analytically. The appropriate radiative transfer and plank's equation was being derived from black body radiation equation were a series of integral homology transformation were used. The method we applied is the Plancks radiation law where we did assume an exponential atmosphere that obeys the Beer-Bouguet-Lambert law of the optical depth equation. The results are in agreement with observational works and the standard theories. However, this work is limited to high approximations.

Key words: Astronomical-objects, Radiation, Magnitudes, Optical-depth, Atmospheric-extinction.

Acknowledgements

I am deeply grateful to my advisor, Mr. Tolu Biressa , for giving me the guidance, insight, encouragement, and independence to pursue a challenging proposal. His contributions to this work were so integral that they cannot be described in words here. I would like to thank my colleagues at Purdue, Student Tariku Tadesse, Wodito W., who helped me out when things got a little too technical. And to my friends at Purdue, thank you for four memorable years, it was really hard to leave in the end. Finally, I would like to thank , my family complete the final in financial stretch of this work. In addition to all of the opportunities and support that they have provided in the computer writing skill.

I would like to thank my families for their moral and financial supports during my study. Also I am thankful to my friends and colleagues for their comments and supports. I would like to thank my instructors and all staff members in the physics department for their support during my study.

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Chapter 1

General Introduction

1.1 Background and Literature review

The field of astronomy have developed from simple observation(by eye) about the movement of sun and moon in to sophisticated theories of the universe. Celestial measurements reaching back 3000 years or more carried out in many cultures world wide. Observational astronomy is the practice of observing celestial object by using telescope and other astronomical tools and focused on getting data, in contrast with theoretical astrophysics which is mainly concerned with finding out the measurable implication of physical model. Astronomical [18]observation depends on the transition of the earth's atmosphere caused by the turbulence and related optical refractive index variation. Turbulence in earth's atmosphere is a major obstacle to the detection of planets with chronographic and interferometer methods from the ground. Observational astrophysics uses sophisticated technology to collect and measure electromagnetic radiation from beyond the earth[1].

Modern observatories produce large, complex data sets and extracting the maximum possible information from them requires the expertise of specialists in many fields beyond the physics and astronomy from civil engineers to statisticians and soft ware engineers. Everyone knows that astronomy makes use of optical telescopes for the observation of sky objects in the wave length range from ultraviolet to infrared, that is from about 300nm to30μm. Although the recent years have seen the development of space astronomy from automatic telescopes by satellites, the huge cost of these satellites and some of their inherent limitations will mean that ground based telescopes will be still for many decades and perhaps centuries the main instrument of astronomers.

The first astronomy practiced was optical astronomy and measuring star brightness is an ancient idea. Up to Galileo Galilei(1609), the most important means of observation in astronomy was the human eye. But Over the centuries,astronomers have developed the capability of their instruments to give them greater power to detect and measure astronomical sources. Modern astronomy began in the renaissance with the observations of Tycho Brahe and Galileo and the theoretical work of Kepler and Newton. At the beginning of the 17th century telescope was invented in Holland and in 1609 Galileo Galilei made his first astronomical observations with this new instrument. The progress of our knowledge of the sky may be traced through a series of major discoveries which often follow the development of new technologies such as the telescope, computers, and space observatories. This thesis introduces the essentials of professional astronomical observations to colleagues in allied fields, to provide context and relevant background for both facility construction and data analysis. Seeing also varies with time and direction in the sky[2] .

It covers the path of electromagnetic radiation through telescopes, optics, detectors, and instruments, its transformation through processing into measurements and information, and the use of that information to improve our understanding of the physics of the cosmos and its history. The object that astronomers study including: stars, planets and galaxies produces radiation indifferent ways depending on their physical properties,example:- composition, density, temperatures and environments. This means that they will emit different amounts of radiation at different wave lengths. This radiation[3] is modified on its way to earth by interaction with intervening gas and dust inter stellar materials found between stars, but not within galaxies. An incoming plane wave is perturbed by the earth's atmosphere turbulent structure leading to the phase errors. Therefore the atmosphere is almost always turbulence and observation is affected by **weather** and **air flow** over the surface of the earth, so it is varies with **location**, **climate** and **topography**.

In radio astronomy atmospheric conditions are not very critical except when observing at the shortest wave lengths. Constructors of radio telescopes have much greater freedom in choosing their sites than optical astronomers still; radio telescopes are also often constructed in uninhabited places to isolate them from distributing radio and television broadcasts. In optical telescopes it fulfills three major tasks in astronomical observations. it collects light from a large area, making it possible to study very faint sources. In addition, it also increases the apparent angular diameter of the objects resolution and to measure the position of objects. Alight collecting surface in telescope is either a lens or a mirror. The most important points of view is effects on astronomical observation in earth's atmosphere caused by atmospheric turbulence and related optical refractive index variation. These astronomical observations on effects of earth's atmosphere can be organized according to their position, structures, and formation of astronomical objects and bodies . In addition to their role in the dynamics of astronomical objects, they are believed to be influence by electromagnetic spectrums. Turbulence in earth's atmosphere is a major obstacle to the detection of planets with chronographic and interferometer methods from the ground. An incoming plane wave is perturbed by the earth's atmosphere turbulence structure leading to phase errors. Therefore the atmosphere is almost always turbulence.

1.2 Statement of the Problem

The central idea of this thesis is to identify the atmospheric effects on astronomical observation in earth's atmosphere. In astronomy one often must observe very faint objects. To understand this astronomers take observation in remote mountain and what factors to capture the missing electromagnetic radiation. That is why the large observatories have been built on a mountain tops far from the cities. Therefore Observation is the most important to observe about astronomical objects and bodies. Most of the astronomical observation focuses on fundamental astrophysics to collect and measure electromagnetic radiation beyond the earth. The second major purpose of astronomical observation using telescope is to precisely determine the location in the sky from which radiation is emanating. A more recent observations have begun to probe the more discriminative strong field system. So the main purpose of this research thesis is to work on accreting astronomical observation effects on earth's atmosphere.

Research Question

1. How does earth's atmosphere affect radiations coming from astronomical sources?
2. What is the effect of earth's atmosphere on astronomical photometry and spectroscopy?

3. What factors affect astronomical observation on earths atmosphere?
4. Why are most astronomical observation built on remote mountain?

1.3 Objectives

1.3.1 General objective

To study the effects of earths atmosphere on astronomical observation.

1.3.2 Specific objectives

- To determine the effects of earth's atmosphere on radiations coming from astronomical sources.
- To calculate photometric and spectral distortions due earth's atmosphere.
- To describe factors that affect astronomical observation due to earths atmosphere.
- To explain where astronomical observation instruments be placed for better image capture.

1.4 Materials and Methodology

Planck's radiation law is being used to derive relevant parameters like brightness magnitudes (such as apparent, absolute, bolometric magnitudes), and other observable parameters. In particular the atmospheric extinction is being considered by assuming an exponential atmosphere. Then the optical thickness related to extinction is an exponential one, where the Beer-Bouguer-Lambert law is considered. Finally the analytically derived equations are used to generate numerical data using MATHEMATICA software for the analysis of the results.

Chapter 2

Introduction to Astronomical Observation Fundamentals

The fundamental astronomical observation in astrophysics uses a sophisticated technology to collect and measure electromagnetic radiation from beyond the earth. Turbulence in earth's atmosphere is a major obstacle to the detection of planets with chronographic and interferometer methods from the ground. This thesis introduces the essentials of professional astronomical observations to colleagues in allied fields, to provide context and relevant background for both facility construction and data analysis. It covers the path of electromagnetic radiation through telescopes, optics, detectors, and instruments used to improve our understanding of the physics of the cosmos and its history.

Measuring the radiation from astronomical objects and interpreting those measurements is what observational astrophysicists do. Developing physical models to predict and explain the radiation detected from astrophysical objects is the domain of theoretical astrophysicists. For objects which radiate in all directions (most but not all astrophysical [23]objects), the received intensity decreases with the square of the distance from the source. Only a tiny fraction of the radiation from an astrophysical object is aimed in our direction, and that fraction is smaller for more distant objects. Astronomicalobservers[21] are very often working in the low signal-to-noise regime, at the very edge of detect ability. Astronomical observations are nearly always passive we have no ability to directly manipulate or experiment with the objects of interest. In most cases we rely on radiation emitted from these objects reaching our telescopes[15].

This is in contrast to active remote sensing, such as sonar or radar, where radiation is transmitted to the object and scattered or reflected back for detection. Active sensing beyond Earth is confined to radar studies of objects within the solar system: objects beyond the solar system are simply too far away for a signal to return in a detectable way or in a reasonable period of time! Direct[19] physical contact with the object of interest occurs in only a few situations within the solar system. Most commonly, meteorites fall to Earth from space; spacecraft[6] missions have also yielded a few samples returned from the surfaces of solid bodies or particles collected from the solar wind. Rather than observational astronomy, this kind of study would usually be called planetary science (meteorites and solid bodies) or space physics (solar wind). Astrophysics is unique among sciences in the range of size scales involved. It explores relationships between the largest and smallest scales, from the observable universe to the smallest subatomic particles. Both the technology used to make observations, and the physics used to interpret them, span a similar broad range. Observational astrophysicists need to be familiar with a variety of experimental, statistical and computational techniques and technologies.

2.1 Basic Tools and Parameters In Astronomical Observation

There are three basic components of a modern system for measuring radiation from astronomical sources: the telescopes, the wavelength-sorting device, and the detectors. Astronomy is now carried out across the entire electromagnetic spectrum from radio to the gamma ray as well as cosmic ray, neutrinos, and gravitational waves. Observational astronomy may be divided according to the observed region of the electromagnetic spectrum. Some parts of the spectrum can be observed from the Earths surface, while other parts are only observable from either high altitudes or outside the Earths atmosphere. For this reason astronomers use different tools to observe astronomical objects.

Optical Telescope- The light-collecting surface in a telescope is either a lens or a mirror[17]. Thus, optical telescopes are divided into two types, lens telescopes or refractors and mirror telescopes or reflectors.

Optical astronomy - The first astronomy practiced by eye and all observational astronomers studied the visible light that the human eye sees. Visible-light(optical)astronomy uses optical components (mirrors, lenses and solid-state detectors) to observe light from near infrared to near ultraviolet wavelengths.Incorporate a wide range of observations through telescope that are sensitive in the range of visible light about 320 to 900 nm .

A radio telescope- Radio telescope represents relatively new branch of astronomy. It covers a frequency range from few megahertz(100m) up to frequencies of about 300GHz(1mm), thereby extending the observable electromagnetic spectrum by many order of magnitude[10]. The low -frequency limit of the radio band is determined by opacity of the ionosphere while the light frequency limit is due to the strong absorption from oxygen and water.

Radio astronomy - studies astronomical object at radio frequency examining their emission of electromagnetic radiation[4] in the radio portion of the spectrum at ground based because at broad region of radio wave earths atmosphere is transparent but at the highest radio frequencies (λ 1mm, in the microwave band)the atmosphere is opaque and this region must be carried out above the atmosphere. Overcoming the effects of the earth's atmosphere on astronomical observation is to entirely block some wave lengths of the lights.
This below figure 2.1 shows the bands of the electromagnetic spectrum and how well Earths atmosphere transmits.
Turbulence [9]induces refraction of radiation which slightly changes its direction. The net effect of these slight changes is to blur images of astronomical sources such that their angular sizes are larger than they would be without the atmosphere. This phenomenon, called seeing, sets the spatial resolution of ground-based infrared and visible-light [5]telescopes with sizes larger than about 10 cm. Seeing is quantized by

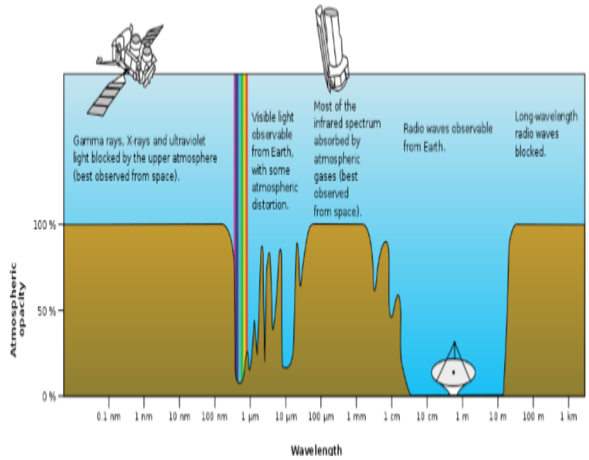

Figure 2.1: Electromagnetic spectrum and it's transmittance through Earth's atmosphere.

measuring the full-width at half-maximum of a point source. The blurring caused by seeing not only makes point sources appear larger in angular size, it also spreads out the light from objects with angular sizes larger than the spatial resolution. This reduces the signal-to-noise of measurements and the ability of telescopes to see detail. The seeing is the wavelength dependent. So the equations are as follows,

$$r_0[\lambda]\alpha\lambda^{\frac{6}{5}} = \lambda^{1.2}(coherence\ length) \tag{2.1.1}$$

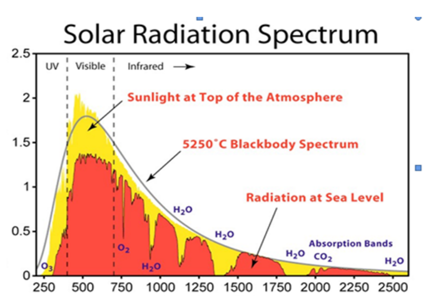

Figure 2.2: The effect of the atmosphere on the sun light.

$$\tau_0[\lambda]\alpha\lambda^{\frac{6}{5}} = \lambda^{1.2}(coherence\ time) \tag{2.1.2}$$

$$\theta_0[\lambda]\alpha^{\frac{6}{5}} = \lambda^{1.2}(isoplanetic\ angle) \tag{2.1.3}$$

This above figure 2.2 shows the effect of atmosphere on the radiation. It is a worse at shorter wave lengths and better at a longer wavelength with satellites and space crafts, observation can be made outside the atmosphere. Yet the great astronomical observations are carried out from the surface of the earth. The atmosphere affects observation in many other ways as well, the air never quite steady, and there are layers with different temperatures and densities this causes convention and turbulence[3]. The turbulence in the earth's atmosphere is always subsonic. To every good degree one can regard the velocity fields to divergence -free. That means the turbulence in the earth's atmosphere is entirely carried by solonoidal i.e. velocity. It is caused by many different phenomena. The atmosphere is turbulent and can schematize as cells of gas inconstant motion. The electromagnetic wave is produced a distorted image [7]. Each individual distorted image is called speckle. Observations with telescopes located on the Earth's surface are affected by the atmosphere. Thus

Telescopes fulfills- three major tasks in astronomical observation i.e.

▷ It collects light from large area making it possible to study very faint source.

▷ It increases the apparent angular diameter of objects and

▷ Thus improves resolution.

The fundamental measurement that an astronomer makes is the amount of radiation [27]from the sky, as a function of direction, time, wavelength or frequency, and polarization. The most important purpose of astronomical telescopes is to act as a 'light bucket.

Geometrical telescope- have two refractive lenses,[22]

▷ the objective which collects the incoming light and

▷form image through eyepieces which is small magnifying glasses for looking at the image. As the number of photons detected from an astronomical source increases, the uncertainty of the corresponding measurement decreases. Because astronomical objects are far away, only a small amount of their radiation reaches us; every last photon can be important. Using larger telescopes allows us to collect more photons, so we can detect fainter objects more quickly, or more slowly subdivide (e.g. in time or wavelength) the light received from brighter objects. The second major purpose of an astronomical telescope is to precisely determine the location in the sky from which radiation is emanating. Focusing the radiation can be done in one of two ways: refraction or reflection.

Refraction is familiar from other optical instruments such as eyeglasses and microscopes, and involves bending of light through a lens material (usually glass). Very large lenses are heavy and can only be supported around their thin edges. Most modern large astronomical telescopes focus light using reflection by curved (usually in the shape of a conic section) mirrors that can be supported from the non-reflecting side. These mirrors can be made of materials similar to familiar everyday mirrorssilver- or aluminum-coated glassor rather different, such as the beryllium mirrors on the James Webb Space Telescope (JWST) or the wire surfaces of a radio telescope. A focusing telescopes ability to precisely measure the direction of radiation **its spatial resolution** is limited by the size of the telescope and the diffraction of light.

Diffraction occurs when waves pass through a narrow opening or across an edge:

the waves spread out and interfere with one another. Diffraction of electromagnetic waves means that even a source of radiation of zero physical size, observed by a telescope of finite size, will generate an image with a finite size.

Ground-based telescopes- are a telescopes, of course observe through the atmosphere, which has to two main consequences on the quality of observations. The first consequence is degradation due to the turbulent variations of the index of refraction while most astronomical catalogs result from deterministic data processing pipelines, new approaches to constructing catalogs based on [24, 25]Bayesian inference are beginning to emerge . This causes the image of a star to appear as a randomly moving patch with an angular size which is often quite larger that the theoretical limit size due to diffraction from the telescope optics. They are cheap and easier to maintain. You can upgrade and use for different instrumental types.

Gamma ray astronomy - studies radiation quanta with energies of $10^5 - 10^{14} eV$. The boundary between gamma and X-ray astronomy, $10^5 eV$, corresponds to a wavelength of 10^{-11} m. The boundary is not fixed; the regions of high-energy (X-rays) and (soft gamma) rays partly overlap. Gamma and hard X-rays are produced by transitions in atomic nuclei or in mutual interactions of elementary particles. Thus observations of the shortest wavelengths give information on processes different from those giving rise to longer wavelengths. The first observations of gamma sources were obtained at the end of the 1960s, when a device in the (OSO) satellite (Orbiting Solar Observatory) detected gamma rays from the Milky Way.

X-ray astronomy includes:- the energies between 10^2 and $10^5 eV$, or the wavelengths $10 - 0.01$nm. The regions $10 - 0.1$nm and $0.1 - 0.01$nm are called soft and

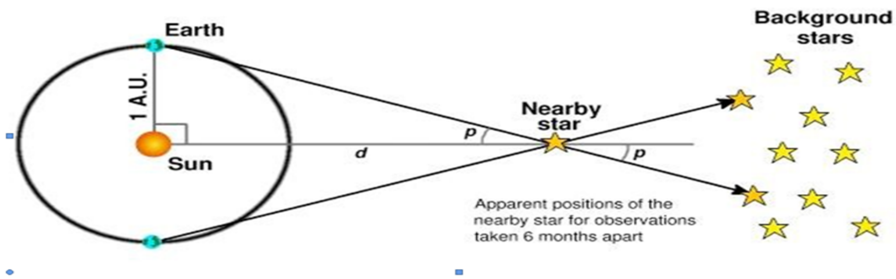

Figure 2.3: The earth orbits the sun, nearest stars seem to move relative to the more distances which appear fixed

hard X-rays,respectively. X-rays were discovered in the late 19th century. Let us note a sun to Earth distance ($a = 1AU = 1.496 \times 10^{11}m$) and the distance of the nearby star:

$$tanp = p(radians) = a/d. \tag{2.1.4}$$

When the light from a star passes through unsteady air,[7] rapid changes refraction, which changes in different directions result. Thus the amount of light reaching detector. For example, the eye constantly varies, the star is said to be scintillate the planets shine more steadily since they are not point sources like the stars. Astronomers decide to measure angles in arc sec. and distance in parsec. One parsec (1pc) is the distance corresponding to a parallax of 1arcsec i.e. the distance to which the sun-earth distance corresponding to 1 arc sec.

2.2 Basic Parameters In Astronomical Observation

2.2.1 Photometric Concepts and Apparent Magnitudes

The measurement of the brightness of radiating objects in the sky is astronomical[16] photometry,Photometry is a technique of astronomy concerned with measuring the flux, or intensity of an astronomical object's electromagnetic radiation and when we deal mainly with,centers around which a region of the electromagnetic spectrum to which the human eye is sensitive is optical photometry[4]. The quantitative measurement of the basic properties of stars and galaxies came from observing the electromagnetic radiation they emit for those earth's atmosphere is nearly transparent around the range of visible light and some infrared(IR), while the other is the radio window in the wave length range 1cm-30m. Most astronomical observations [20] utilize electromagnetic radiation in one way or another. We can obtain information on the physical nature of radiation source by studying the energy distribution of radiation [12]. We shall now introduce some basic concepts that characterize electromagnetic radiation.

2.2.2 Magnitudes

As the magnitudes were introduced by the Greek astronomer Hipparchus 130 BC,the modern magnitude system has its origin in the ancient Greek. Magnitude is a number that measures the brightness of a star or galaxy. In magnitude, higher numbers correspond to fainter objects, lower numbers to brighter objects; the very brightest objects have negative magnitudes. The Hipparchus arranged the visible stars in to six brightness rank,and he called the first rank the brightest and were ranked as six the faintest. The ranks were called magnitude. In daylight the human eye is most sensitive to radiation with a wavelength of about 550nm, the sensitivity decreasing towards red (longer wavelengths) and violet (shorter wavelengths). The magnitude corresponding to the sensitivity of the eye is called the visual magnitude mv. The most accurate magnitude measurements are made using photoelectric photo meters[14]. One of the multi color magnitude systems used widely in photo electric photometry is the UBV system developed in the early 1950's by Harold L. Johnson and William W. Morgan. Magnitudes are measured through three filters,U=ultraviolet,B=blue and V=visual respectively.

The UBV system was later augmented by adding more bands. One commonly used system is the five colour UBVRI system, which includes R=red and I=infrared filters. There are also other broad band systems, but they are not as well standardized as the UBV, which has been defined moderately well using a great number of standard stars all over the sky. The magnitude of an object is obtained by comparing it to the magnitudes of standard stars.

In Strmgren's four-colour or uv by system, the bands passed by the filters are much narrower than in the UBV system. The uv by system is also well standardized, but it is not quite as common as the UBV. Other narrow band systems exist as well. By adding more filters, more information on the radiation distribution can be obtained.

In any multi colour system, we can define colour indices; a colour index is the difference of two magnitudes. By subtracting the B magnitude from U we get the colour index U - B, and so on. If the UBV system is used, it is common to give only the V magnitude and the colour indices U - B and B-V.

2.2.3 Apparent Magnitudes

In apparent magnitudes the first class contained the brightest stars and the six faintest ones still visible to the naked eye. Apparent magnitude is the brightness of an object as it appears to be. The rightness of a star in physical units is its flux which has the units of Watts per square meter in mks.In terms of the magnitude system, the flux is described as an apparent magnitude. However, astronomers almost never use flux to describe brightness of objects, they use magnitude. It depends on how far away the object is from the observer(like an objects flux). The brighter an object appears,the lower its magnitude value(e.i inverse relation ship). It is simply a measure of the apparent flux density of the star as measured from earth.

The response of the human eye to the brightness of light is not linear. If the flux densities of three stars are in the proportion 1:10:100, the brightness difference of the first and second star seems to be equal to the difference of the second and third star. Equal brightness ratios correspond to equal apparent brightness differences: the human perception of brightness is logarithmic. The rather vague classification of Hipparchus was replaced in 1856 by Norman R. Pogson. Since a star of the first class is about one hundred times brighter than a star of the sixth class, Pogson defined the ratio of the brightness's of classes n and n+1 as $\sqrt[5]{100}$=2.512.

2.2.4 Absolute Magnitudes

Absolute magnitude is a concept that was invented after apparent magnitude when astronomers needed a way to compare the intrinsic,or absolute brightness of celestial objects, and astronomers use this magnitudes which stars are truly bright and which are truly faints because distance is no longer variable. There fore it reflects the intrinsic amount of light put out by the source and never changes (like an objects luminosity). It is apparent magnitude that an observer would measure at a distance of d = 10pc from the source and that the source (in the absence of light loss in the intervening space)would have if situated at this distance(10parsec(32ly)). It is a measure of flux at 10pc away from earth. (A light-year is the distance light travels in one year about 6 trillion miles, or 10 trillion kilometers.) 1pc = 206,265AU = 3.08*1016m.

In absolute magnitudes thus far we have discussed only apparent magnitudes. They do not tell us anything about the true brightness of stars, since the distances differ. If we observe an object from different points, we see it in different directions. The difference of the observed directions is called the parallax. Since the amount of parallax depends on the distance of the observer from the object, we can utilize the parallax to measure distances. A quantity measuring the intrinsic brightness of a star is the absolute magnitude. It is defined as the apparent magnitude at a distance of 10 parsecs from the star. We shall now derive an equation which relates the apparent magnitude m, the absolute magnitude M and the distance r. Because the flux emanating from a star into a solid angle $d\omega$ has, at a distance r, spread over an area Ω^2, the flux density is inversely proportional to the distance squared. Therefore the ratio of the flux density at a distance r, F(r), to the flux density at a distance of 10 parsecs, F(10), is the equations as follows:

$$m = -2.5lg\frac{F}{F_0} \tag{2.2.1}$$

For historical reasons, this equation is almost always written as

$$m - M = 5lgr - 5 \tag{2.2.2}$$

which is valid only if the distance is expressed in parsecs. (The logarithm of a dimensional quantity is, in fact, physically absurd.) Sometimes the distance is given in kilo parsecs or mega parsecs, which require different constant terms in (2.2.1). To avoid confusion, we highly recommend the form (2.2.2). Absolute magnitudes are usually denoted by capital letters. Note, however, that the U, B]= and V magnitudes are apparent magnitudes. The corresponding absolute magnitudes are MU, MB and MV.

2.2.5 Bolometric magnitude and Bolometric correction

The bolometric magnitude is a measure of the energy spectral flux density (W m-2 Hz-1) integrated over the entire appropriate frequency band(integrated over all wave lengths). It is a measure of the bolometric flux density F (W/m2) magnitude of a star. Bolometric magnitudes go beyond the restriction of magnitude at some particular wavelength, or range of wavelengths, and refer to the total power of the source and includes those unabsorbed due to an instrumental pass-band,the earths atmospheric absorption and extinction by interstellar dust. It is based upon the total energy flux in and near the optical band (IR, optical, UV). The absolute bolometric magnitude can be expressed in terms of the luminosity. Let the total flux density at a distance r = 10 pc be F and let $F\odot$ be the equivalent quantity for the Sun. Since the luminosity is

$$L = 4\pi r^2 F \tag{2.2.3}$$

The absolute bolometric magnitude Mbol=0 corresponds to a luminosity $L_0 = 3.0 \times 10^{28} W$.

2.2.6 The Bolometric correction

The Bolometric correction the correction applied to a magnitude (apparent or absolute) to get the bolometric value. Then the bolometric correction BCx is defined as

$$m_{bol} = m_x + BC_x \; wherexisstandsfortheparticularpassbands \tag{2.2.4}$$

$$M_{bol} = M_v + BC_v \tag{2.2.5}$$

where the subscript V refers to the V or Visual pass-band (a yellow-green filter) of the UBV or UBVRI photometric systems, and BC is the bolometric correction which is determined as a function of temperature or spectral type. The BCv bolometric correction zero point was derived by assuming for the sun $M_bol = 4.74$ and M_v =4.81 from the observed V = -26.76mag. Thus we assigned visual bolometric correction BCv of -0.07 mag for the solar model. The bolometric correction is 24 then the quantity that must be added to the visual magnitude to obtain the bolo metric one. By definition, the bolometric correction is zero for radiation of solar type stars (or,more precisely, stars of the spectral class

$$BC = mbol - V = M_Bol - M_V \tag{2.2.6}$$

2.2.7 Absolute Bolometric Magnitude and Luminosity

The absolute bolometric magnitude is a direct measure of the bolometric luminosity of a star. It is the energy output integrated over the ultraviolet, visual, and Infrared as fitting for the temperature of the star. The bolometric magnitude M_bol of an arbitrary star is related by luminosity L as :

$$Mbol - Mbol, \odot = -2.5log\frac{L}{L\odot} = \tag{2.2.7}$$

$$Mbol = -2.5log\frac{L}{L\odot} + 4.74 \tag{2.2.8}$$

Where ,$L\odot$ = 3.84510^{26} $M_bol,\odot$ = 4.74 Of the sun. To define the zero point of the absolute bolometric magnitude scale by specifying that a radiation source with absolute bolometric magnitude $M_Bol = 0$ mag has a radiative luminosity of exact has a radiative luminosity of exactly $L0 = 3.0128 * 10^{28}W$ and the absolute bolometric magnitude M_Bol for a source of luminosity L (in W) is

$$Mbol = -2.5log\frac{L}{L\odot} = -2.5logL + 71.17425.. \tag{2.2.9}$$

2.2.8 Intensity, Flux and Flux Density and Luminosity

2.2.9 Intensity

Specific Intensity is the energy per unit area normal to the direction of radiation, per unit solid angle, per unit time, per unit wave length(or frequency). The intensity including all possible frequencies is called **the total intensity I**, and is obtained by integrating $I\nu$ over all frequencies. Let us assuming we have some radiation passing

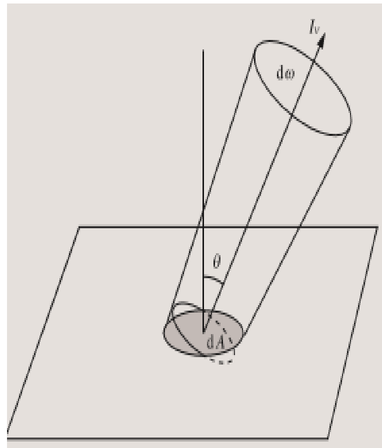

Figure 2.4: The intensity of radiation energy passing a surface element dA in to a solid angle $d\omega$, a direction θ

through a surface element d_A in above (fig2.4). Some of the radiation will leave dA with in a solid angle $d\omega$; the angle between $d\theta$ and the normal to the surface is denoted by θ. The amount of energy with frequency in the range $[\nu, v + dv]$ entering this solid in time dt is

$$dE = Icos\theta dAd\nu d\omega dt \tag{2.2.10}$$

; Where, the coefficient Iv is the specific intensity of the radiation at the frequency ν in the direction of the solid angle $d\omega$. Its dimension is $Wm^{-2}\ Hz^{-1}\ sterad^{-1}$

The projection of the surface element d_A as seen from the direction θ is d_An $=d_A$ cosθ, which explains the factor cosθ. If the intensity does not depend on direction, the energy $d_E\ \nu$ is directly proportional to the surface element perpendicular to the direction of the radiation. The intensity including all possible frequencies is called the total intensity I, and is obtained by integrating Iν over all frequencies:

$$I = \int_0^\infty I_\nu d_\nu \tag{2.2.11}$$

Beer Lambert Law

The law was discovered by pierre Bouguer before 1729, while looking at red wine, during a brief vacation in Alentejo, portugal.

Lambert law states- that the loss of light intensity when it propagates in a medium is directly proportional to intensity and path length. The modern derivation beer modern law combines two laws and correlated the absorbance negative decadic logarithm of the transmittance and thickness of the material sample. It relates to the optical attenuating path length and absorptivity of the species. This expression is

$$A = \varepsilon \ell c \tag{2.2.12}$$

where ε =Molar attenuates coefficient(Absorptivity) ℓ =The optical path length c=The concentration of the attenuating species A more general form of the Beer-Lambert law states that, for N attenuating species in the material sample

$$\tau = \sum_{i=1}^{N} \tau i = \sum_{i=\ell}^{N} \sigma i \int_0^l ni(z) d_z \tag{2.2.13}$$

$$A = \sum_{i=1}^{N} Ai = \sum_{i=\ell}^{N} \varepsilon i \int_0^l ci(z) d_z \tag{2.2.14}$$

where σ=the attenuation cross section of the attenuating species i in material sample. ni= the number density of the attenuating species ci= the amount of concentration of the attenuating species ℓ=the path length of the beam of light through the material sample. In the above eqn., the transmittance τ of material sample is related to its optical depth to its absorbance A by the following definition

$$\tau = \frac{\Phi e^t}{Phie^i} = e^{-\tau} = 10^{-A} \tag{2.2.15}$$

where Φe^t = radiant flux transmitted Φe^i = radiant flux received Attenuation cross section and molar attenuation coefficient are related by

$$\varepsilon i = \frac{N_A}{\ln 10}\sigma i, \tag{2.2.16}$$

and the number density and amount concentration by

$$c = \frac{n_i}{N_A}, \tag{2.2.17}$$

where N_A is the avogadro constant

In case of uniform attenuation these r/n becomes

$$\tau = e^{-\ell}\sum_{i=1}^{N}\sigma_i n_i = 10^{-\ell}\sum_{i=1}^{N}\varepsilon_i c_i \tag{2.2.18}$$

equivalently

$$A = \ell\sum_{i=1}^{N}\varepsilon_i c_i. \tag{2.2.19}$$

In case of non- uniform attenuation occur in atmospheric science applications and radiations shielding theory for instance the law tends to break down at highly concentrations, specially if the material is highly scattering. Absorbance b/n 0.2-0.5 is ideal to maintain the linearity Beer Lambert law.

Expression with attenuation coefficient The Beer Lambert law can be expressed in terms of attenuation coefficient, but in this case is better called Lambert's law since amount concentration , from Beer's law, is hidden inside the attenuation coefficient. The (Napierian) attenuation coefficient μ and decadic coefficient can be $\mu 10 = \frac{\mu}{\ln 10}$ of a material sample are related to its number densities and amount concentration as

$$\mu_z = \sum_{i=1}^{N} \mu_i(z) = \sum_{i=1}^{N} \sigma_i n_i(z) =, \sum_{i}^{N} \varepsilon_i c_i(z) \tag{2.2.20}$$

respectively, by definition of attenuation cross section and molar attenuation coefficient. Then the Beer lambert law becomes

$$\tau = e^{-\int_0^\ell} \mu(z) d_z = 10^{-\int_0^\ell} \mu_{10}(z) d_z \tag{2.2.21}$$

In case of uniform attenuation, these relation becomes

$$\tau = e - \mu\ell = 10 - \mu 10^{\ell}, \tag{2.2.22}$$

equivalently $\tau = \mu\ell$

$$A = \mu_{10}\ell. \tag{2.2.23}$$

In many cases, the attenuation coefficient does not vary with z.

$I_(z) = 1_0 e^{-\mu z}$

2.2.10 Flux and Flux density

More important quantities from the observational point of view are the energy flux ($L\nu$, L) or, briefly, the flux and the flux density ($F\nu$, F). The flux density gives the power of radiation per unit area; hence its dimension is $Wm^{-2}Hz^{-1}$ or Wm^{-2}, depending on whether we are talking about the flux density at a certain frequency or about the total flux density. Observed $flux$ densities are usually rather small, and Wm^{-2} would be an inconveniently large unit. Therefore, especially in radio astronomy, flux densities are often expressed in Janskys; one Jansky (Jy) equals $10^{-26}Wm^{-2}Hz^{-1}$. When we are observing a radiation source, we in fact measure the energy collected by the detector during some period of time, which equals the *flux* density integrated over the radiation-collecting area of the instrument and the time interval. The flux density $F\nu$ at a frequency ν can be expressed in terms of the intensity as

$$F\nu = \frac{1}{d_A d_v d_t} \int_s dE_v \tag{2.2.24}$$

$$= \int_s I_v \cos\theta d\omega \tag{2.2.25}$$

where the integration is extended over all possible directions. Analogously, the total *flux* density is

$$F = \int_s I \cos\theta d\omega \tag{2.2.26}$$

Suppose we have some radiation leaving the surface element $d_A$in the direction θ. The energy entering the solid angle d_ω in time dt is

$$d_E = I cos\theta d_A d_\omega dt \tag{2.2.27}$$

where I is the intensity. If we have another surface d_A' at a distance r receiving this radiation from direction θ, we have r receiving this radiation from direction

$$d_\omega = \frac{d_A' cos\theta'}{r^2} \tag{2.2.28}$$

Substitution of $d\omega$ and $d\omega'$ into the expressions of d_E gives $I' cos\theta' dA' \frac{dA' cos\theta dt}{r^2}$

$\Rightarrow I' = I$ Thus the intensity remains constant in empty space. Assume that the Sun radiates isotropically. Let R be the radius of the Sun, $F\odot$ the flux density on the surface of the Sun and F the flux density at a distance r. Since the luminosity is constant,the flux density equals L= $4\pi R^2 F_0 = 4\pi r^2 F$

$$F = F \odot \frac{R^2}{r^2} \tag{2.2.29}$$

At a distance $r \gg$ R, the Sun subtends a solid angle

$$\omega = \frac{A}{r^2} = \frac{\pi R^2}{r^2} \tag{2.2.30}$$

where A $=\pi R^2$ is the cross section of the Sun. The surface brightness B is

$$B = \frac{F}{\omega} = \frac{F\odot}{\pi} \tag{2.2.31}$$

Applying (2.2.28) we get

$$B = I\odot \tag{2.2.32}$$

2.2.11 Luminosity

Luminosity is an expression of true brightness of an object how much radiation is emitted per second. It is also a measure of the radiative power of a source, and relates to the entire output,and thus can be directly connected with absolute bolometric magnitude. The most basic stellar property we can think of measuring is its luminosity and one of the basic direct observable quantities for star. It depends where star is in its evolutionary sequence (the effective temperature), size of a star and extinction. one of the basic direct observable quantities for star. As the radius increases, the surface area will also increase, and the constant luminosity has more surface area to illuminate, leading to a decrease in observed brightness. Measuring luminosity means deriving accurate measurements, for each of these components and without which an accurate luminosity figure remains elusive . To measure total luminosity, assuming that no light is absorbed during its journey out side of the shell i.e at $r \gg R$and by neglecting any effect(relativistic effect)then the inverse square law for the energy flux is cogent.

$$F = \frac{L}{A}, \tag{2.2.33}$$

$$F = \frac{L}{4\pi r^2} \tag{2.2.34}$$

Where$A = 4\pi^2$ r is the surface area of the illuminated sphere with radius r and r is the distance from the observer to the light source, F is flux density$\Rightarrow L = 4\pi r^2$ The inverse square law for energy flux out side of the star at a distance $r > RisF\alpha\frac{1}{r^2}$, Where R is radius of star. The total luminosity of star is the product of surface area and the radiation emitted per area. L = $A\sigma T^4$ (assuming the star is a black body) L = $4\pi R^2$ where σ is the Stefan-Boltzmann constant.

2.2.12 Extinction by Earths Atmosphere at Optical Wave Lengths and its Variabilities

In areal observations a number of effects can complicate the picture. The theoretical celestial brightness requires accurate models of many effects, among them atmospheric extinction is one. Since the first pointing of a telescope towards the sky by Galileo Galilei, the extinction properties of the atmosphere have hampered the astronomical observations made with the instruments placed on the Earths surface. Our knowledge of celestial objects must take into account absorption and scattering of photons as they travel to earth observers. As light[26] propagates to us from its sources it experiences various opportunities to interact with material. As a result the flux of the observed object reduced. Attenuation causes the strength of the signal to drop off rapidly after traveling a few kilometers. Then to allow ground based observations the exact knowledge of properties of earth's atmosphere and correction for the effect is needed. Because the correction for optical atmospheric extinction is one of the crucial steps for achieving accurate spectrophotometry from the ground.

In making these observations, we must also correct for the effect of the Earths atmosphere. So generally my concern is the astro physically uninteresting attenuation from the four hurdles faced by an astronomical photon and air mass. It is useful to define the mean-free path,ℓ, for a photon and the related opacity and optical depth.

2.2.13 Optical depth

The opacity of a material is a measure of its ability to absorb light. The dimensionless parameter, $\tau\nu$ describing the opacity extinction at frequency ν. In particular, the infinitesimal increase in optical depth along a line of sight $dt\nu$, is related to the infinitesimal path length dr according to.

$$d_L = -\alpha L d_T \tag{2.2.35}$$

$$d_T = \alpha d_T \tag{2.2.36}$$

Where α is the factor tells how effectively the medium can obscure radiation. It is called the opacity. Next integrate this from the source (where L = L_0 and r = 0) Opacity extinction substitute

$$d_L = -d_{TL} \tag{2.2.37}$$

$$\int_{L_0}^{L} -\frac{dL}{L} = \int_{T0}^{T} -d_T \tag{2.2.38}$$

Opacity(extinction) reduces the flux of a source according to

$$L\nu, obs = L\nu, 0e^{\tau} \tag{2.2.39}$$

Where τ is the optical thickness(depth) of the material between the source and the observer,depending on wavelength and cloud properties. Gas with $\tau_\lambda >> 1$ is optically thick and if $\tau_\lambda << 1$ the gas is optically thin. L, is the observed flux,$L\nu$, 0 is the unextincted flux (i.e., $\tau = 0$) The flux L falls off exponentially with increasing optical thickness. Empty space is perfectly transparent $\alpha = 0$ thus the optical thickness does not increase in empty space, and the flux remains constant. Now we want to find out how the extinction depends on the distance. Assume we have a star radiating a flux L0 into a solid angle θ in some wavelength range. Since the medium absorbs and scatters radiation, the quantity X is the air mass. According to the equation below, the magnitude increases linearly with the distance r

$$X : m = m_0 + kX, \tag{2.2.40}$$

2.2.40) where k is the extinction coefficient.

The extinction coefficient can be determined by observing the same source several times during a night with as wide a zenith distance range as possible. The observed magnitudes are plotted in a diagram as a function of the air mass X. The points lie on a straight line the slope of which gives the extinction coefficient k. Atmospheric extinction as we mentioned in equation(2.2.40), the Earth's atmosphere also causes extinction. The observed magnitude m depends on the location of the observer and the zenith distance of the object, since these factors determine the distance the light has to travel in the atmosphere. To compare different observations, we must first reduce them, i.e. remove the atmospheric effects somehow. The magnitude m0 thus obtained can then be compared with other observations. If the zenith distance z is not too large, we can approximate the atmosphere by a plane layer of constant thickness (Fig. 2.4). If the thickness of the atmosphere is used as a unit, the light must travel a distance

$$X = 1/cosz = secz \tag{2.2.41}$$

in the atmosphere. The quantity X is the air mass. According to (2.2.29), the magnitude increases linearly with the distance X: If the zenith distance of a star is z, the light of the star travels a distance H/cosz in the atmosphere; H is the height of the atmosphere. This line is extrapolated to X = 0, we get the magnitude m_0, which is the apparent magnitude outside the atmosphere. In practice, observations with zenith distances higher than70^0 (or altitudes less than20^0 are not used to determine k and m0, since at low altitudes the curvature of the atmosphere begins to complicate matters. The value of the extinction coefficient k depends on the observation site and time and also on the wavelength, since extinction increases strongly towards short wavelengths.

2.2.14 Black Body Radiation

The ideal black body notion(here after the black body is of primary importance in studying thermal radiation and electromagnetic radiation energy transfer in all wave length bands. Being an ideal radiation observer,[11] the black body is used as standard with which absorption of real bodies is compared. As we have seen later, the black body also emits maximum amount of radiation and, consequently, it is used standard for comparison with the radiation of real physical bodies.

This notion introduce by G.Kirchof in 1860, is so important that it is actively used in studying not only the intrinsic thermal radiation of natural media, but also the radiation caused by different physical natures. More over this notion and its characteristics are some times used in describing and studying artificial quasi-deterministic electromagnetic radiation(in Radio and TV broad casting and communication).

A black body is an object which is a perfect absorber (absorbs at all wavelengths) and a perfect emitter (emits at all wavelengths) and does not reflect any light from its surface. Black body is an ideal body which allows the whole of the incident radiation to pass in to it self (with out on the energy). This properties is valid for radiation corresponding to all wave lengths and to all angles of incidence. Therefore the black body is an ideal absorber of incidence radiation. All other qualitative characteristics determining the behavior of a black body follow from this definition (see for example, Siegel and Howell ,1972;Ozisik,1973).

.... A black body not only absorbs radiation ideally,but possesses other important properties which will be considered below. Consider a black body at constant temperature, placed inside a fully insulated cavity of arbitrary shape, whose walls are also formed by ideal black bodies at constant temperature, which initially differs the temperature of the bodies insides. To prove this, we shall consider what would happen if the incoming and out going radiation energies were not equal. In this case the temperature of the body placed inside a cavity would begin to increase or decrease, which would correspond to heat transfer from a cold to a heated body.

At any given radius r in the atmosphere:

$$4\pi r^2 F(r) = const. = L \tag{2.2.42}$$

F is the energy flux per unit surface and per unit time. Dimensions: [erg/cm2/sec].

2.2.15 Radiation and Temperature

As atoms and molecules move about and collide,or vibrate in place, their electrons give off electromagnetic radiation. The characteristics of this radiation are determined by the temperature of those atoms and molecules. The energy transport is sustained by the temperature gradient. The steepness of this gradient is dependent on the effectiveness of the energy transport through the different atmospheric layers. Mechanisms of energy transport a. radiation: F rad (most important) b. convection: F conv.(important especially in cool stars) c. heat production: e.g. in the transition between solar cromosphere and corona d. radial flow of matter: corona and stellar wind e. sound waves: cromosphere and corona in a transport of energy we will be mostly concerned with the first two mechanisms: F(r)=Frad (r) + Fconv (r). In the outer layers we always have $Frad \gg Fconv$

Temperatures of astronomical objects range from almost absolute zero to millions of degrees. Temperature can be defined in a variety of ways, and its numerical value depends on the specific definition used. All these different temperatures are needed to describe different physical phenomena, and often there is no unique 'true' temperature. Often the temperature is determined by comparing the object, a star for instance, with a black body. Although real stars do not radiate exactly like black bodies, their spectra can usually be approximated by black body spectra after the effect of spectral lines has been eliminated. The resulting temperature depends on the exact criterion used to fit Planck's function to observations. The most important quantity describing the surface temperature of a star is the effective temperature Te. It is defined as the temperature of a black body which radiates with the same total flux density as the star. Since the effective temperature depends only on the total radiation power integrated over all frequencies, it is well defined for all energy distributions even if they deviate far from Planck's law. If we now find a value Te of the temperature such that the Stefan-Boltzmann law gives the correct flux density F on the surface of the star, we have found the effective temperature. The flux density on the surface is

$$F = \sigma Te^4 \tag{2.2.43}$$

The total flux is $L = 4\pi R^2 F$, where R is the radius of the star, and the flux density at a distance r is

$$F' = \frac{L}{4\pi^2} = \frac{R^2}{r^2 F} = \left(\frac{\alpha}{2}\right)^2 \sigma Te^4 \tag{2.2.44}$$

where $\alpha = 2R/r$ is the observed angular diameter of the star. For direct determination of the effective temperature, we have to measure the total flux density and the angular diameter of the star. This is possible only in the few cases in which the diameter has been found by interferometry. If we assume that at some wavelength $\lambda$the flux density $F\lambda$ on the surface of the star is obtained from Planck's law, we get the brightness temperature Tb.

In the isotropic case we have then$F_\lambda = \pi B_\lambda(Tb)$. If the radius of the star is R and distance from the Earth r, the observed flux density is

$$F'_\lambda = \frac{R^2}{r^2} F_\lambda \tag{2.2.45}$$

Again $F\lambda$ can be determined only if the angular diameter is known. The brightness temperature Tb can then be solved from

$$F_\lambda = \left(\frac{\alpha}{2}\right)^2 B_\lambda(T_b) \tag{2.2.46}$$

Since the star does not radiate like a black body, its brightness temperature depends on the particular wavelength used in (2.2.34). The ideal black body notion(here after the black body is of primary importance in studying thermal radiation and electromagnetic radiation energy transfer in all wave length bands. Being an ideal radiation observer,[11] the black body is used as standard with which absorption of real bodies is compared.As we have seen later, the black body also emits maximum amount of radiation and, consequently, it is used standard for comparison with the radiation of real physical bodies. Tb gives the temperature of a black body with the same surface brightness as the observed source. Let I! be the intensity of radiation perpendicular to the bottom surface going into a solid angle $d\omega([I_v] = Wm-2Hz-1sterad-1)$. If the intensity changes by an amount dI_v in the distance dr, the energy changes by in the cylinder in time dt.

$$d_E = dI_v dA d_V d\omega dt \tag{2.2.47}$$

This equals the emission minus absorption in the cylinder. The absorbed energy is (c. f. (2.2.55))

$$d_E abs = \alpha I_v dr dA d_V d\omega dt \tag{2.2.48}$$

where α_v is the opacity of the medium at frequency ν . Let the amount of energy emitted per hertz at frequency ν into unit solid angle from unit volume and per unit time be $j\nu([j\nu] = Wm^{-3}Hz^{-1}sterad^{-1})$. This is called the emission coefficient of the medium. The energy emitted into solid angle d from the cylinder is then

$$d_E em = j_v dr dA d_v d\omega dt \tag{2.2.49}$$

The equation

$$d_E = -dEabs + dEem \tag{2.2.50}$$

gives then

$$dI_v = -\alpha_v dr + j_v dr or \tag{2.2.51}$$

$$\frac{dI_v}{\alpha_v dr} = -I_v + \frac{j_v}{\alpha_v} \tag{2.2.52}$$

We shall denote the ratio of the emission coefficientj_v to the absorption coefficient or opacity $\alpha_v by S_v$:

$$s_v = \frac{j_v}{\alpha_v} \tag{2.2.53}$$

S_v is called the source function. Because $\alpha_v dr = d\tau_v$, where ν is the optical thickness at frequency ν , (2.2.46) can be written as

$$\frac{dI_v}{d\tau_v} = -I_v + s_v \tag{2.2.54}$$

Equation (2.2.48) is the basic equation of radiative transfer. Without solving the equation, we see that if $I\nu < S\nu$, then $dI\nu/d\tau\nu > 0$, and the intensity tends to increase in the direction of propagation. And, if $I\nu > S\nu$, then $dI/d\tau\nu < 0$, and $I\nu$ will decrease. In an equilibrium the emitted and absorbed energies are equal, in which case we find from (2.2.45) and (2.2.46)

$$I_v = \frac{j_v}{\alpha_v} = S_v \tag{2.2.55}$$

(2.2.48) Substituting this into (2.2.47), we see that$dI_v/d\tau_v = 0$. In thermodynamic equilibrium the radiation of the medium is black body radiation, and the source function is given by Planck's law:

$$S_v = B_v(T) = \frac{2h\nu^3}{c^2} \frac{1}{e(\frac{h\nu}{KT-1})} \tag{2.2.56}$$

The shorter the wavelength of the radiation, the larger the amount of energy carried by that radiation. Radiation transfer is also a major way of energy transfer between the atmosphere and the underlying surface and between different layers of the atmosphere. It comes in an infinite number of wavelengths. Visible radiation is too energetic to be absorbed by most of the gases in the atmosphere and not energetic enough to photo dissociate them, so that the atmosphere is almost transparent to it. The single factor that determine how much energy is emitted by a black body is its temperature. The intensity of energy radiated by a black body increases according to the fourth power of its absolute temperature.

So, in the band a lot of surfaces approach an ideal black body in their ability to absorb radiation (examples of such surfaces are: Soot, Silicon carbide, Platinum, and Gold niellos). However the out visible light region wave length band of IR thermal radiation and in the radio frequency bands, the situation is different. So the majority of the Earth's surface(the water, ice land) and absorb infra red radiation well, for this reason, in the thermal IR band these physical objects are ideal black bodies.

Wiens displacement law states that the black body radiation curve for different temperature peaks at a wavelength that is inversely proportional to the temperature. The shift of that peak is a direct consequence of the Planck radiation law, which describes the spectral brightness of black body radiation as a function of wavelength

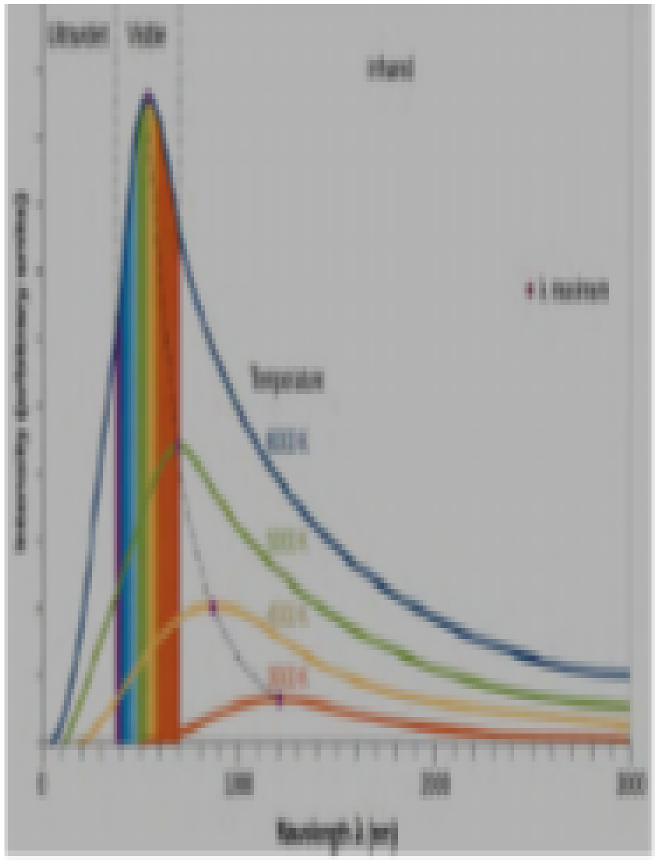

Figure 2.5: Plank radiation law as a function of spectral brightness of black body radiation at any given temperature

at any given temperature. Stars: emit as black body in the UV to NIR. The black body spectrum peaks at a Planck's law is continuous.

2.2.16 Spectra

Electromagnetic spectrum refers to the full range of all frequencies of electromagnetic radiation and also to the characteristics distribution of electromagnetic radiation emitted by the particular object. The spectral distribution of electromagnetic radiation from a celestial object can reveal much about the physical processes taking place at the object. By obtaining and analyzing the spectrum from a distant we can identify what type of object it is and determine a wealth of characteristics for the object. A black body not only absorbs radiation ideally, but possesses other important properties which will be considered below. Consider a black body at constant temperature, placed inside a fully insulated cavity of arbitrary shape, whose walls are also formed by ideal black bodies at constant temperature, which initially differs the temperature of the bodies insides. After some time the black body and the closed cavity will have a common equilibrium temperature. Under equilibrium conditions the black body must emit exactly the same amount of radiation as it absorbs. To prove this, we shall consider what would happen if the incoming and out going radiation energies were not equal. In this case the temperature of the body placed inside a cavity would begin to increase or decrease, which would correspond to heat transfer from a cold to a heated body.

Three general types of spectra were now known, a continuous spectrum and two types of line spectra.

continuous spectrum - showing all the component colors of the rainbow,and the overall hill-shaped spectrum of electromagnetic radiation emitted by a black body then it is produced by thermal emission from a black body. Such a spectrum contains no lines because light of all colors is present in it.

Absorption spectrum - dark-line spectra like the solar spectrum and those from stars or continuous spectrum, but with the ?ux of certain frequencies reduced because something absorbed them between the source and Earth.

Emission spectrum - bright-line spectra as emitted from gas discharge tubes and some nebulae. An emission spectrum looks very different rather than a continuous spectrum, we see emission at specific wavelengths. Because it can only emit those same wavelengths that it can absorb, and those wavelengths will depend on the atoms comprising the gas. The formation of spectral lines is quantized with the radiation transfer equation. Its solution for different conditions gives insight to the formation of both absorption and emission lines. An absorption line can be diagnosed by superposed lie upon a continuum spectrum. An emission line may or may not be superposed upon a continuum spectrum

2.2.17 Plank's law

The idea of light in the form of energy quanta of size $h\nu$ was introduced by Planck to explain the radiation energy B(T)emitted by a black body as a function of frequency(wave length) and temperature T, per unit frequency, surface area, viewing solid angle and time. Many interesting phenomena emitting thermal radiation follow approximately the theoretical curve of a black body radiation. To determine the temperature and other properties of such body Planck's law becomes a source of information about them. Planck's law gives the spectral distribution of electromagnetic emission for a black body at a given temperature. The Planck function is derived in the frequency domain using the method of oscillators. To derive the form of a black-body spectrum we need to apply some elementary quantum mechanics and to know the number density of photon states for a given energy level and the average energy of each state, using Boltzmann formula. Planck postulated that atoms oscillating in the walls of the cavity have discrete energies given by

$$E = nh\nu \tag{2.2.57}$$

$$\triangle E = nh\nu \tag{2.2.58}$$

$$\triangle E = E_n h + 1 - E_n = h\nu \tag{2.2.59}$$

$$E_n = nh\nu \tag{2.2.60}$$

for n=0,1,2,3,....., where n is integer (quantum number),h is Planck's constant, ν is frequency and $\triangle E$ is quantum of energy emitted when an atom changes its energy state. For energy of a mode En, there are n photons in the mode. Each photon has an energy equal to $h\nu$, the energy of a mode is quantized. To obtain the probability n photons P(n)in the mode of frequency, we start from the definition temperature Boltzmann factors(According to statistical mechanics, when local thermodynamic equilibrium (LTE) holds in the material, the state populations will obey a Boltzmann distribution proportional to $e\frac{-E}{KT}$. Where E is the state energy, T is temperature, and k is Boltzmanns constant.

$$P(E_n) = Ae\frac{-E}{KT} \tag{2.2.61}$$

A is normalizing constant

$$\sum_{n=0}^{\infty} P(E_n) = A\sum_{n=0}^{\infty} e\frac{-nh\nu}{KT} = 1 \tag{2.2.62}$$

The sum of all the probabilities must be 1. using the fact that:

$$< n >= \sum_{n=0}^{\infty} nPn = 1 - e\frac{-h\nu}{KT} \sum_{n=0}^{\infty} ne\frac{-h\nu}{KT} \tag{2.2.63}$$

$$\sum_{0}^{\infty} ne\frac{-h\nu}{KT} \tag{2.2.64}$$

Where $\alpha = \frac{h\nu}{KT}$

$$\sum_{n=0}^{\infty} ne^{-\alpha n} = -\frac{\partial}{\partial x}(\frac{1}{1 - e^{-\alpha}}) = \frac{e^{-\alpha}}{(1 - e^{-\alpha})^2} \tag{2.2.65}$$

$$< n >= \frac{e\frac{h\nu}{KT}}{1 - e\frac{-h\nu}{KT}} \tag{2.2.66}$$

$$< n >= e\frac{h\nu}{KT} \times 1 - e\frac{-h\nu}{KT} \tag{2.2.67}$$

or

$$< n >= \frac{1}{e(\frac{h\nu}{KT-1})} \tag{2.2.68}$$

$$< n >= e^{(\frac{h\nu}{KT-1})} \tag{2.2.69}$$

is the thermal average distribution of photons plank's distribution. Multiplying this number by energy per photon($h\nu$), it gives the mean thermal energy.

$$< \bar{E}_n >= h\nu < n >= \frac{h\nu}{e^{(\frac{h\nu}{KT-1})}} \tag{2.2.70}$$

this equation is the average energy per mode or quantum is the energy of the quantum times the probability that it will be occupied.

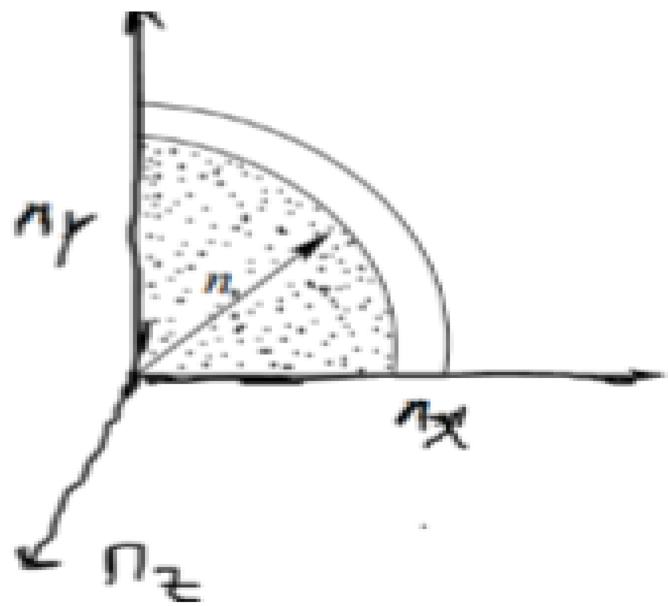

Figure 2.6: The triplet of each integers (nx, ny, nz) has a side of standing wave $\frac{c}{2L}$

2.2.18 The Planck distribution in terms of the energy density of radiation per unit frequency and wave length interval

To show this we need the number of modes of oscillation of electromagnetic wave in a cavity in the frequency interval ν to $\nu + d\nu$ per unit volume, consider a one dimensional box of side L and in equilibrium only standing waves are possible, and these will have nodes at the ends. X = 0, L.

$$\frac{L}{\lambda} = \frac{n_x}{2}, n_x = 1, 2, 3, ... \tag{2.2.71}$$

$$n_y = \frac{2L}{\lambda}, n_y = 1, 2, 3, ... \tag{2.2.72}$$

$$n_z = \frac{2L}{\lambda}, n_z = 1, 2, 3, ... \tag{2.2.73}$$

In 3D, each triplet of integers (nx,ny,nz) correspond to a possible mode of standing wave inside the cavity. To find the number of modes with frequency between ν and $\nu + d\nu$, look at an array of points. Each point in this space, i.e each triplet of positive integers (nx,ny,nz), represents a mode and each points represent two mode and are distributed uniformly in this space, so there are two modes per unit volume of n-space.

$$\lambda = \frac{c}{\nu} \Rightarrow \nu = \frac{n \times c}{2L} \tag{2.2.74}$$

$$n = (n_x^2 + n_y^2 + n_z^2)^{\frac{1}{2}} \tag{2.2.75}$$

is the radius of sphere in n-space. Actually the number of triplets of positive integers is equivalent to the volume of one octant of the space(one-eight of the spherical shell) whose thickness is dn. Then the number of modes that lie between n and n + dn is equal to the number of n-space points inside the spherical shell times two. The volume of spherical shell of radius n and dn is $4\pi n^2 dn$ and so the number of modes in the octant is $2(\frac{1}{8})4\pi n^2 dn$. The factor 2 comes from two possible states of polarization for each standing wave. If we convert the result in terms of frequency.

$$n = \frac{2L}{\lambda} = \frac{2L\nu}{c}, d_n = \frac{2L}{c} d_v = \tag{2.2.76}$$

$$\left(\frac{\pi \mathrm{L}^2 V^2}{c}\right)\left(\frac{2L}{c}\right) d_\nu \tag{2.2.77}$$

Let $N(\nu)d\nu$ represent the number of standing waves in the cavity in $[\nu, \nu + d\nu]$, then we get the result

$$N(_\nu)d_\nu = \frac{8\pi L^3 v^2}{c^3} d_v \tag{2.2.78}$$

$$N(_\nu)d_\nu = \frac{8\pi L v^2}{c^3} d\mu \tag{2.2.79}$$

L^3 has been replaced by V of the cavity and this equation is the number of modes of oscillation in the frequency interval $\nu\ to\ \nu + d\nu$. Thus, per unit volume, the number of states is

$$N(_\nu)d_\nu = \frac{8\pi L v^2}{c^3} d\nu \tag{2.2.80}$$

the factor $4\pi v^2 d_v$ is the volume of thin spherical shell. When the system is in thermal equilibrium each mode of oscillation will attain the same energy E. Therefore, the energy density of radiation per unit frequency interval per unit volume is, multiplying the number of mode of standing wave whose frequency lies between ν and $\nu + d\nu$(eqn 2.2.84) by average energy(eqn 2.2.83) and divide by the volume of cavity. $U(\nu)d\nu$ is the energy per unit volume between ν and $\nu + d\nu$ is, expressed in terms of either frequency or wavelength:

$$d\mu = N_v d_v = \frac{(N(v)(d(_v)E}{v^3} \tag{2.2.81}$$

The Stefan Boltzmann law for the energy density distribution of black body radiation- is the energy radiated in one second by one square meter of the black-bodies surface is directly proportional to the fourth power of its temperature. To find the dependence of the total energy density of radiation U up on temperature is integrating the planck's spectrum over all frequencies or wavelengths.

$$U = \int_0^\infty \mu(_v)d_v \tag{2.2.82}$$

$$U = 8\pi hc^3 \int_0^\infty e^{\left(\frac{\mathrm{h}\nu}{\mathrm{KT}-1}\right)} \tag{2.2.83}$$

Change the variable to $x = \frac{h\nu}{KT}, d_v$, then

$$U = \frac{8\pi h}{c^3} \left(\frac{\mathrm{KT}}{h}\right)^4 \int_0^\infty \frac{x^{3dx}}{e^{x-1}} \tag{2.2.84}$$

$$U = \alpha T^4 \tag{2.2.85}$$

$\alpha = \frac{8\pi^5 K^4}{15c^3h^3}$ is radiation constant. Specific intensity is generally related to the differential amount of radiant energy, d_E, that crosses an area element, d_A, in directions confined to differential solid angle d Ω

$$dE_v = B_v cos\theta dAd_v d\Omega dt \tag{2.2.86}$$

where B_v is the specific intensity of radiation at the frequency ν in the direction of the solid angle $d\Omega$. Its dimension is $Wm^{-2}Hz^{-1}$

$$\frac{d_E}{d_\nu} = 8\pi hv^3c^3 \frac{1}{e^{\left(\frac{\mathrm{h}\nu}{\mathrm{KT}-1}\right)}} \tag{2.2.87}$$

$$d_E = \mu_v d_v = 8\pi h\nu^3 c^3 \frac{1}{e^{\left(\frac{\mathrm{h}\nu}{\mathrm{KT}-1}\right)}} dAd\nu d\omega dt \tag{2.2.88}$$

$(B_v, T) cos\theta dAd_v d\Omega dt$

$$B(_v, T) = \frac{8\pi v^3 cdtdAdv}{c^3 e^{\left(\frac{\mathrm{h}\nu}{\mathrm{KT}-1}\right)}} dAd\omega dt \tag{2.2.89}$$

$\nu = cdtdA \; and \; d\omega = 4\pi$

The specific intensity for black body radiation, the Planck radiation law, in terms of the frequency ν and temperature T(absolute temperature), is

$$B(_v, T) = \frac{2h\nu^2}{c^2} \frac{1}{e^{\left(\frac{\mathrm{h}\nu}{\mathrm{KT}-1}\right)}} \tag{2.2.90}$$

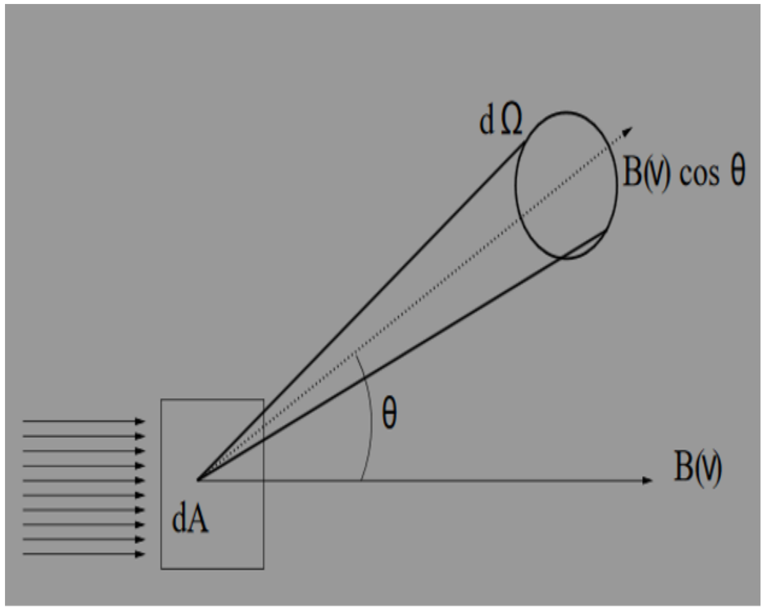

Figure 2.7: Intensity of energy passing through area dA in a solid angle $d\omega$/t/λ

is planck's function of spectral radiance in $Wm^{-2}Hz^{-1}sr^{-1}$) where $h = 6.626 * 10^{-34}Js$ and $k = 1.381 * 10^{-23}Jk^{-1}$ are the Planck and Boltzmann constants and c $= 3 * 10^8$m the speed of light. frequency ν at The planck's law as spectral radiance function in the wave length domain is $Bvdv = -B\lambda d\lambda$ the minus sign indicates that the wave length decreases with increasing frequency

$$c = \lambda_v \Rightarrow = \frac{c}{\lambda} \tag{2.2.91}$$

$$\frac{d_v}{d\lambda} = \frac{c}{\lambda^2} \tag{2.2.92}$$

$$B_\lambda = -B_v \frac{d_v}{d_\lambda} \tag{2.2.93}$$

$$B\lambda = B_v \frac{c}{\lambda^2} \tag{2.2.94}$$

$$B(v,T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\left(\frac{\mathrm{h}\nu}{\lambda \mathrm{KT}-1}\right)}} \tag{2.2.95}$$

2.2.19 Effective Temperature

This temperature is the temperature that the object would have if it were a perfect black body. That is, the effective temperature of a star is the temperature of a black body that would emit the same total amount of electromagnetic radiation and with the same luminosity per surface area (F$_{B}ol$) as the star and is de?ned according to the Stefan-Boltzmann law FBol=$\sigma T^4 eff$. L=$4\pi\sigma R^2 T^4 eff$ where R is the star radius. It is the most important physical quantity often used as an estimate of a body's surface temperature when the body's emissivity curve (as function of wavelength) is not known.

$$T_{eff} = \frac{L}{(4\pi\sigma R^2)^{\frac{1}{4}}} \tag{2.2.96}$$

If the flux density at a distance r is

$$F = \frac{1}{4\pi r^2} = \frac{R^2}{r^2} F = \left(\frac{\alpha}{2}\right)^2 \sigma T^4_{eff} \tag{2.2.97}$$

Where $\alpha = 2$R r is the observed angular diameter of the star. For direct determination of the effective temperature, we must measure the total flux density and the angular diameter of the star. If we assume that at some wavelength λ the flux density Fλ on the surface of the star is calculated from planck's law, we get the brightness temperature Tb In the isotropic case :

$$F'_\lambda = \pi B_\lambda(T_b) \tag{2.2.98}$$

$$F'_\lambda = \frac{R^2}{r^2} F'\lambda \qquad (2.2.99)$$

$$F'_\lambda = (\frac{\alpha}{2})^2 \pi B_\lambda(T_b) \frac{1}{e^{\frac{hc}{\lambda KT - 1}}} \qquad (2.2.100)$$

2.2.20 Gas Pressure and Radiation Pressure

Considering non interacting particle of a rectangular box of photons consisting of a cubic sides of the box be Δ_x, Δ_y and Δ_z, and the number of particles, N. The pressure is caused by the collisions of the particles with the sides of the box. When a particle hits a wall perpendicular to the x axis, its momentum in the x direction, px, changes byδ P = 2Px. The particle will return to the same wall after the time Δ_t=2$\Delta_{x/vx}$ and thus the surface area A=Δ_y Δ_z is

$$P = \frac{F}{A} = \frac{\frac{\sum \Delta P}{\Delta t}}{A} = \frac{\sum P_x v_x}{\Delta_x \Delta_y \Delta_z} = \frac{N(P_x v_x)}{V} \qquad (2.2.101)$$

where V =Δ_x Δ_y Δ_z is the volume of the box and the angular brackets represent the average value. The momentum is px =mv_x (where m = hν/c^2 for photons), and hence

$$P = \frac{Nm(v_x)^2}{V} \qquad (2.2.102)$$

Suppose the velocities of the particles are isotropically distributed.

Then $(v_x)^2 = (v_y)^2 = (v_z)^2$, thus

$(v)^2 = (v_x)^2 + (v_y)^2 + (v_z)^2 = 3(v_x)^2$ and

$$P = \frac{Nm(v)^2}{3V} \qquad (2.2.103)$$

If the particles are gas molecules, the energy of a molecule is E= 2mv^2. The total energy of the gas is E=N($_\varepsilon$) =$\frac{1Nm^2}{2}$, and the pressure may be written P= $\frac{2E}{3v}$ (gas) .

If the particles are photons, they move with the speed of light and their energy is $\varepsilon = mc^2$. The total energy of a photon gas is thus E=(N_ε)=Nmc^2 and the pressure is P= $\frac{1E}{3v}$ (radiation) . According to (4.7), (4.4) and (5.16) the energy density of black body radiation (in fundamental astronomy) is

$$\frac{E}{V} = u = \frac{4\pi I}{c} = \frac{4F}{c} = \frac{4\sigma T^4}{c} \equiv aT^4, \tag{2.2.104}$$

where $a = 4\frac{\sigma}{c}$ is the radiation constant. Thus the radiation pressure is

$$P(_{rad}) = \frac{aT^4}{3} \tag{2.2.105}$$

Chapter 3

Result and Discussion

To study the effects of earths atmosphere on the stars spectra and so comparing to the results of our treatment examples as found in the literature. The flux of an astronomical object measured on earth needs to be corrected for effects. A completely uniform,opaque medium in thermal equilibrium at temperature T that in thermal equilibrium the photons have to follow a particular distribution, called the Planck function. Planck Spectrum (Exoatmospheric intensity or un attenuated intensity), at T= 0

The set of summarized relevant equations are;

1. Planck's radiation law

   a) Without extinction

$$B_\lambda = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1} \tag{3.0.1}$$

   b) The intensity with extinction, where exponential atmosphere is assumed or where the Beer-Bouguet-Lambert law is considered for optical depth

$$I_\lambda = I_{0\lambda} e^{-\tau} \tag{3.0.2}$$

Or in terms of B

$$B_{\lambda_{ex}} = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda kT}}-1}e^{-\tau} \tag{3.0.3}$$

2. Magnitudes

a) Using the relative apparent magnitude relation we derive the excess magnitude created in the atmospheric extinction

$$\Delta m = m_{ext} - m_{noext} = 2.5\tau sec\theta \log[e] \tag{3.0.4}$$

b) Also the excess magnitude in the bolometric magnitude as the result of the atmosphere is

$$\Delta M_{bol} = 2.5\tau sec\theta \log[e] \tag{3.0.5}$$

With a particular temperature, $T = 10000K$ of typical stellar, the effect of atmosphere on the intensity and magnitudes received at the observation point on earth with air mass of 20 & 70 degrees both seeing with optical depth 0f 0.2 & 0.7 have been used to generate a numerical data computationally using MATIMATICA. The results are displayed as in 3.1 & 3.2. AS we can see from the plots of 3.1 the intensity observed decreases in the present of atmosphere. The more optical depth of the atmosphere is the more it decreases the intensity. Moreover, the more air mass the seeing taking is the more the extinct it is.

The same phenomena also observed in the magnitudes as we see from 3.2.

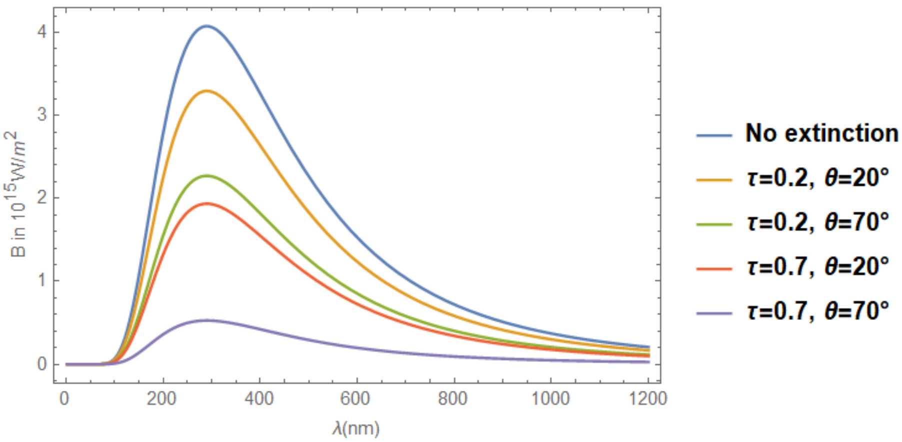

Figure 3.1: Effect of atmosphere on intensity. Intensity without extinction is being compared in the presence of extinction

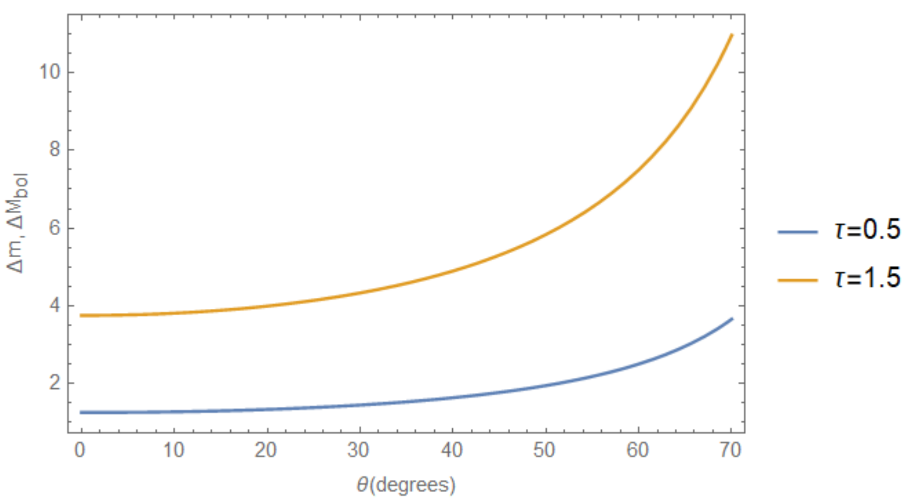

Figure 3.2: Effect of atmosphere on magnitudes. Both apparent and bolometric magnitudes without extinction are being compared in the presence of extinction

Chapter 4

Summary and Conclusion

Astronomical object's observation is affected by different factors like atmospheric extinction such as absorption, scattering, atmospheric emission, clouds, dust particles in the air, air mass and motion of the air. That this extinction reduces the electromagnetic radiation that is coming from the object to the earth.

It is important to make observation repeatedly rather than observing ones, in different time in a place with no dust in air, no cloud, and more or less no motion of air as well as at high altitude and small zenith angle to decrease air mass.

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