Chapter 1

INTRODUCTION

In this Chapter, a brief history of the development of cometary science is discussed. The definition of comet, its structure, classification and the origin are also discussed. Different observational techniques to understand the nature of the cometary dust like photometric, polarimetric and spectroscopic measurements and the in-situ measurements are also discussed in this chapter.

1.1 General Introduction

1.1.1 Historical Perspective of Cometary Science

Comets are several kilometer in diameter, constituted mainly of water ice and rock. They are basically dirty snowballs, sometimes hard and icy, sometimes
soft and fluffy, originally formed in the outer Solar System, at or beyond the orbit of Jupiter, then flung to the outer edges of the Solar System during the period of heavy bombardment more than 4.5 billion years ago. Thus comets are undoubtedly the most volatile-rich of all surviving remnants from the early solar system. The name comet comes from the Latin Phrase ‘Stellae comatae’ which means hairy stars.

Comets have attracted and fascinated the people for more than two thousand years. The first listing of comet in recorded history was done by Chinese observation in 240 B.C. They spend almost all their time at great distances \((10^5 - 10^6 \text{AU})\) from the Sun. The comets becomes brighter and spectacular with coma and tail as it approaches near the Sun. This fascinating celestial object has always remained a matter of study for the human beings and is evident from the ancient records of paintings or drawings of comets on caves, clothes etc. Tycho Brahe developed the ideas about comets by observing the bright comet of 1577 AD to understand that comets are solar system objects. Kepler in 1619, proposed that comets follow straight lines path and they originate outside the Solar System. Hevelius suggested parabolic orbits for comets in 1668, but Newton argued against a parabolic orbit of the comet of 1681. The contribution of Edmund Halley in comet studies has revolutionised the ideas about comets. Halley for the first time, using Newtonian Mechanics, showed that the comets, which had appeared in 1531, 1607 and 1682, are the one and
the same comet with a period of about 75.5 years. He predicted that the same comet would return in 1758. The comet did appear in 1758, as predicted, but unfortunately Halley was not alive to see his glorious prediction. This famous comet was therefore named as Halley’s comet. In 1986, the same comet again appeared in the Sky (after 1910 apparition) and research workers from all over the world have studied that historical comet with a great interest.

1.1.2 Structure of comets

The three major parts of a comet are the nucleus, the coma and the tail. A comet far from the sun consists of a dense solid body or conglomerate of bodies a few kilometers in diameter called the nucleus. The nucleus is the essential part of a comet because it is the only permanent feature that survives during the entire life time of a comet. Several attempts have been made to determine the size of the nucleus (e.g., Delsemme & Rudd 1973; Sagdeev et al. 1986a; Wilhelm, 1986, 1987; Sekanina 1997a; Kruchinenko and Churyumov 1997; Weaver et al. 1996; Fernandez et al. 1999;). The nuclear radius of comet Tago Sato Kosoka and comet Bennet as determined by Delsemme & Rudd (1973) were $2.2 \pm 0.27 km$ and $3.76 \pm 0.46 km$ respectively. The size of the nucleus is so small that it appears as a point source and can’t be resolved even with the largest telescope. The direct determination of the size of the nucleus of a comet was made possible by the study of comet Halley. The images
1.1.2: Structure of comets

taken by the spacecrafts directly gave the projected dimension. Based on three spacecrafts results (Vega 1, 2 & Giotto), it was then possible to reconstruct the actual three dimensional shape of the nucleus. From these images, the dimension of the nucleus of comet Halley was estimated to be $16 \times 8 \times 7.5\text{km}$ (Sagdeev et al. 1986; Wilhelm, 1986, 1987). The estimated total surface of the nucleus was about $400 \pm 80\text{km}^2$ and its volume was about $550 \pm 165\text{km}^3$ (Keller et al. 1987a). It has been found that volatiles coming out of the nucleus of a comet are mostly made up of elements like H, C, N and O (Clark et al. 1986). Analysis of Hubble Space Telescope (HST) images of comet Halebopp C/1995 01 suggest that the effective diameter of the nucleus is between 27 to 42 km which is three times larger than that of the comet 1p/Halley (Weaver et al 1996). Measurements taken by HST in visible light and Spitzer Space telescope (SST) in IR light suggest a low albedo of about 4% and measures the nucleus of the comet Tempel 1 to be 7.6x4.9 km. Also the mean effective diameter of the comet LINEAR is found to be 0.88km.

Giotto, a European space craft, launched in 1986 has revealed that comet Halley consists 80% of water, 10% of CO$_2$ and 2.5% of mixture of methane and ammonia. The spacecraft mission, Deep Impact, launched by NASA in 2005 was aimed to study the composition of the interior of the 9P/Tempel-1. The mission revealed that comet like Tempel-1 formed far from Sun is expected to have greater amount of ice with low freezing temperature like ethane. The 300
1.1.2: Structure of comets

kg robotic space probe, namely Stardust mission launched by NASA in 1999 to collect sample from the comet Wild-2 was completed in 2006. The findings revealed that the dust of comet Wild-2 mainly contain organic compounds like nitrogen, amorphous silicates, in addition to crystalline silicates such as olivine and pyroxene with a small proportion of hydrous silicates and carbonate minerals. On the other hand the star dust mission second mission to comet Tempel-1 was aimed to map the comet nucleus geology and also to give a first look at the changes to the comet Tempel-1. ‘Rosetta’ is another robotic space craft mission aimed to study the comet 67P Churyumov-Gerasimarko launched in 2004 which will intercept the comet on 2014.

When a comet approaches the Sun the nucleus becomes enveloped by a luminous ‘cloud’ of dust and gases called the coma; this luminosity is caused by the molecules absorbing and reflecting the radiation of the sun. The nucleus consists of frozen water and gases with particles of heavier substances interspersed throughout, thus being in effect a large, dirty snowball, although more recent research has suggested that comets may contain a higher proportion of dust and rock. The diameter of the coma is much larger and lies in the range of about $10^3$ to $10^5$ km.

As the comet approaches the sun, the solar wind drives particles and gases from the near the surface of the nucleus and coma to form a tail which can extend as much as $10^8 km$ in length. Comets lose material and thus brightness
with successive passages near the sun. Some of this material moves around
the comet’s orbit as a stream of meteoroids; when the earth passes through
this path, a meteor shower is observed. If the comet is sufficiently active, then
the gas and dust ejections take place on a large scale so that two tails may
form. One is wide and curved which is due to scattering of solar light by dust
and is known as dust tail (or Type II tail). The other is narrow and straight
which is caused by ionised gases fluorescing under excitation from ultraviolet
solar radiation and is known as ion tail (or plasma tail or Type I tail). The
tail of ionised gases is always directed away from the Sun. Based on the study
of the ion tail of comets, the existence of the Solar wind was first postulated
(Biermann, 1951).

1.2 The origin of comets: The Oort Cloud

The earlier theories about the cometary origin includes the hypothesis of forma-
tion of solar system suggested by Kant (1755). With the help of his hypothesis
he confirmed the existence of comets in the same way as the planets in the
nebula. Laplace suggested that the comets are extra-solar in origin, while
Opik (1932) was first to suggest a cloud of comets surround the solar system.
This idea was confirmed by the Dutch Astronomer Jan Hendrick Oort (1950).
According to the storage-cloud hypothesis of J. H. Oort, a spherical shell of
more than (100) billion comets surrounds the solar system at a distance of 75,000-150,000 AU. While the comets move very slowly in this huge storage cloud, a passing star may change their orbits enough to force some of them into the inner part of the solar system.

Any modern theory about cometary origins must first explain the origin of the Oort cloud. None of the comets observed today left the Oort cloud more than three or four million years ago. The Oort cloud is, however, gravitationally bound to the solar system, which it follows in its orbit around the Milky Way Galaxy. Therefore, it is likely that the Oort cloud has existed for a long time. The most probable hypothesis is that it was formed at the same time as the giant planets by the very process that accreted them. V. S. Safronov developed this accretionary theory of the planetary system mathematically in 1972. In effect, the Oort cloud in this theory becomes the necessary consequence and the natural by-product of the accretion of the giant planets. In most theories Oort clouds comets formed in the Jupiter-Neptune region. The present day calculation shows that Oort cloud may contain $10^{12}$ comets. Due to perturbation of nearby passing stars, 5 to 10% of comets leave the Oort cloud forever and some other enter the planetary system (Sen & Rana 1992). Among these some may happen to come close to Sun and get detected as observable comets. Sometimes comets may come from another population of comets from a region, which is believed to contain $10^8$ to $10^{10}$ comets in the
1.2: The origin of comets: The Oort Cloud

ecliptic plane beyond the orbit of Neptune between 30 and 50 AU. This region is known as the **Kuiper Belt**. About 200 long period comets have been studied using more accurate and high precision data (Marsden et al. 1978). The age of a comet is generally measured by the reciprocal of the semi-major axis, i.e., $a^{-1}$. New comets coming from the Oort cloud for the first time have $a > 10^4$ AU or $(1/a) < 100 \times 10^{-6}$ AU$^{-1}$. With successive passages the orbit shrinks gradually due to planetary perturbations and hence the value of $(1/a)$ becomes larger and larger. In other words, $(1/a)$ gives a measure of the comet's dynamical age.

The idea that comets can be formed in the inner Solar System is highly unlikely because, the presently known chemical compositions of comets require a temperature at the time of formation to be quite low ($100 K$) to keep the volatiles like H$_2$O, CO$_2$, CO, NH$_3$ and CH$_4$ from evaporating. This led to the other possibility that the comets were formed in the outer parts of the nebula that formed the planets. However STARDUST results predict that comets formed in high temperature region of the solar system. The chemical composition of the Solar System bodies can roughly be divided into three classes depending upon the characteristics of the elements present in them. As for example, hydrogen, helium and other noble gases stay in gas phase even at low temperature, ice melts at moderate temperature and lastly the terrestrial materials like Si, Mg and Fe melt at higher temperature (Whipple, 1972). It
1.3 Classification of comets:

Comets may be classified as periodic and non-periodic in nature and their orbits can be described by conic- section. From the knowledge of the eccentricity ($e$) of the comet, the periodicity can be predicted. For periodic comets, $e < 1$ where as for non-periodic comets, $e \geq 1$. The periodic comets are classified into two categories: (1) Short period comets and (2) Long period comets. Comets with an orbital period less than 200 years are known as Short Period comets. These comets are indicated by a “P/” before the names (viz., 1P/Halley, 23P/Bromen-metcalf, 27/P Crommelin etc.). Comets that have period greater than 200 years are called Long Period comets (viz., Hale-Bopp, Hyakutake etc.). The Short Period comets that have period between 20 years $< T < 200$ years, are known as Halley type comets and the comets that have period ($T$) $< 20$ years are known as Jupiter family comets (viz., 2P/Encke, 21P/Giacobini-Zinner, 22P/Kopff etc.), because the orbits of Jupiter family comets are governed by Jupiter’s gravitational field. Comets
have been classified as ‘old’ and ‘new’, based purely on their orbital characteristics. Comets that have made several perihelion passages around the Sun are generally termed as ‘old’ and those, which are entering for the first time, are called ‘new’. If the direction of the comet’s motion is same as that of the Earth’s motion, it is said to have a direct orbit. If they are in opposite directions, the comet is said to have a retrograde orbit.

1.4 Nature of cometary dust

The spectacular view of a comet is mainly caused due to a cloud of micrometer sized dust particles of density less than even the smoke of a cigarette and of dimension of about $10^5 \text{km}$. The dust originates from a central source of ice and dust, called nucleus. As the ice undergo sublimation the dust get entrained with the gas stream going out of the nucleus. The particles of different sizes move with different speeds and are separated in the dust tails and so the dust particles can be characterised according to the sizes and their speeds of emission from the sphere of influence of the coma. According to the composition and observational geometry comets are classified as very dusty comets, which are very bright like Bennett (1970 I), medium dusty comets like Tago-Sato-Kosaka (1969 IX) and almost dust free comets which display only a ion tail like Ikeya (1963 I). Since comet dust can only be observed from earth by its
scattered light, the knowledge about dust is restricted to particles that provide most of scattering cross section. These particles range from $1 - 10 \mu m$. However larger grains of about $100 \mu m$ are also observed occasionally in antitails. Before Halley encounters the dust size distributions was determined only from optical observations of dust tails. Prior to Halley encounters the presence of silicates, the metals Na, K, Ca, Mn, Fe, Co, Ni, Cu, and possibly Si and Al was known to be composition of cometary dust. It was supposed that cometary dust composition is similar to that of carbonaceous chondrites. The \textit{in-situ} measurements done by the three space craft missions namely Giotto, Vega-1 and Vega-2 revealed that

(i) cometary dust is composed of a silicate components and a refractory organic components termed as ‘silicates’ and ‘CHON’ respectively.

(ii) The average abundance of the rock forming elements are same as their abundance in carbonaceous chondrites and in the Sun. (iii) The abundance of CHON elements are much higher than in any meteorites.

So it is concluded that cometary dust is transported from the coma into the tail. Since the colour of the dust reflects the solar spectrum it can easily be inferred that particles scattering the Sunlight are larger than the wavelength of visible light ($0.4 \mu m - 0.6 \mu m$), typically between 1 and $10 \mu m$ in size. In exceptional cases the small submicrometer and large millimeter sized particles appear in the visible display. However the size range of particles released
from comets nucleus may not be restricted to the range that scatter visible light. Therefore we adopt that cometary particles range from cluster of a few molecules of several millimeter in size to chunks of cometary matter about a meter across. Both theoretical consideration (Shu’man 1992; Fanale and Salvail 1984; Brin and Mendis 1979) and experimental simulations (Ibadinov et al. 1987; Grun et al. 1987b) show that after sublimation of ice-dust mixtures a mantle of dry dust builds up over the ice, the thickness of which may range from millimeters to centimeters before it quenches further sublimation. Pressure build up in this mantle can further lead to disruption of mantle and eruption of particles at speeds of several meters per seconds (Grun et al. 1989).

It is believed that comets are formed within the same dusty gas nebula as the larger bodies of the solar system, like the planets except at a different place. However because of their small size which implies the absence of large scale geologic differentiation and mixing processes, one may expect that the isotopic chemical and molecular characteristics of the presolar materials are best preserved in comets. The main aim of the mission to comet Halley in 1986 was to study the composition of dust and gas in coma.

Interplanetary dust particles (IDP) of cometary origin provide us an insight into the nature of the solid components of comets. However our knowledge about the nature of the volatile components of the cometary nucleus is based on the spectroscopic observations when cometary nuclei interact with
1.4: Nature of cometary dust

solar radiations. The early study revealed that the joint occurrence of the CHON elements with silicates strongly points to the presence of an organic components in the dust particles, and this component is refractory relative to the frozen gases in the nucleus (Jessberger et al. 1986). Greenberg (1982) also predicted a refractory organic component in the cometary dust. The information regarding molecular composition of this component was inferred by Kissel and Krueger (1987a) from PUMA1. According to them the organic component consists of highly unsaturated hydrocarbon polymers and somewhat fluffy mineral which is embedded in a more fluffy mantle of refractory organic mineral. Organic species inferred to be present in the interplanetary dust particles such as polycyclic aromatic hydrocarbon (Allamandola et al. 1987) or in Halley dust such as polyoxymethylene (Huebner 1987). The observational characteristics such as the dust colour, albedo, polarisation etc can be estimated from the visual, near infrared, and mid-infrared observation. The solar light scattered by dust in cometary coma (optically thin media) is partially linearly polarised. The degree of linear polarisation by definition a dimensionless number -1 to +1, which does not depend on the distance of the scattering from the Sun and to the observer.

Stardust mission launched by NASA collected samples from the coma of the comet Wild-2 in 2006, and then the star dust intercepted comet Tempel-1 in 2011 which was also visited by Deep Impact in 2005. The findings revealed
that the dust of comet Wild-2 mainly contain organic organic compounds like nitrogen, amorphous silicates, in addition to crystalline silicates such as olivine and pyroxene. Hydrous silicates and carbonate minerals were also found to be present.

The theory of scattering of plane EM waves by dust grains was presented by Mie (1908) assuming the dust particles to be spherical in shape and immersed in a homogeneous isotropic medium. Several investigators (Safronov et al. 1972; Noguchiet al. 1974; Kiselev and Chernova 1979, 1981; Myers & Nordsieck 1984; Kikuchi et al. 1987; Sen et al. 1987; Sen et al. 1991a, b; Das et al. 2004) have studied the cometary polarisation using Mie theory. The observed polarization data of comet Bradfield has been taken from Kikuchi et al. (1989) and Chernova et al. (1993). The individual monomer in a cluster play an important role in scattering simulations, which is seen in several work of aggregate dust model (Kimura et al. 2003, 2006; Petrova et al. 2004; Hadamcik et al. 2006; Bertini et al. 2007; Das et al. 2008a, b; Das et al. 2010; Paul et al. 2010). Using aggregate dust models with BAM2 geometry and moderate porosity (P≈0.6), Shen et al. (2009) reproduced albedo and polarization for cometary dust, including negative polarization observed at scattering angles beyond 160°. Using aggregate dust model, Das et al. (2008a, b), Paul et al. (2010); Das et al. (2010) successfully reproduced the polarization curves including negative branch observed for comets C/1990 K1 Levy, C/1995 O1
Hale-Bopp, C/1996 B2 Hyakutake and C/2001 Q4 NEAT.

Photometric, Spectrometric and Polarimetric (Optical) measurements on comets are some of the major techniques to understand the nature of the cometary dust. Both ground based and spacecraft observation were carried out on different comets. Also observations at other wavelengths (e.g. Infrared, Ultra Violet, X-ray and Radio) also give important information about the nature of the cometary dust. Several observational techniques are discussed below:

1.4.1 Photometry (Optical)

Astronomical photometry involves the measurement of the light flux from a celestial object at several wavelengths. In order to have a uniform data different observers have to use the same kind of detectors during observation. It is also valuable to isolate and measure certain portions of the spectrum containing features that indicate physical conditions of the celestial bodies (stars, comets etc.) by using a detector with a broad spectral response with individual spectral regions isolated by filters. Every observer should match the detector and filters as closely as possible to a common system called standard stars so that observations of the same non-variable stars, of known magnitudes and colours, will allow each observer to determine his (her) own coefficients. It is then possible to measure the magnitudes of any celestial objects and transform the
results to a common photometric system. Thus by specifying the detector, filters and a set of standard stars, photometric system can be defined (Henden & Kaitchuck, 1982). Most estimates of comet magnitudes have been done by visual or photographic methods. However, Charge Coupled Device (CCD) observations of comets have become of widespread use in the post Halley era. Comets in general possess a continuum in the visible region of the spectrum. The strength of the continuum varies from comet to comet and with the heliocentric distance for the same comet. The observed continuum is attributed to the scattering of the solar radiation by the dust particles. Therefore, the dusty comets should have a strong continuum. But at certain wavelengths, however, the continuum features are contaminated due to the cometary molecular line emissions. Therefore, the continuum has to be corrected for these emission features or a spectral region has to be selected where the emission features are absent or minimal. Since the last apparition of comet Halley (1985-86), observers have been using a set of bandpass interference filters, centered at \( \lambda = 3650, 4845, 6840 \)Å (with FWHM 80Å, 65Å and 90Å respectively) to avoid contamination by line emission. Such filters, commonly known as IHW (International Halley Watch) filters have made comparison of photometric data of various comets easy. IHW had also suggested an additional set of five narrow band interference filters to study molecular emissions: \( \text{C}_2 \) (5140Å), \( \text{C}_3 \) (4060 Å), \( \text{CN} \) (3871 Å), \( \text{OH} \) (3090 Å), \( \text{CO}^+ \) (4260 Å) bands.
1.4.1: Photometry (Optical)

The photometric study of the comets will be helpful to measure the nuclear size of comets at large heliocentric distances (Svoren, 1982; Larson, 1980; Cochran et al. 1980; Weaver et al. 1997; Schleicher et al. 1997; Lee et al. 2011 etc.). The brightness of a comet depends upon three factors: (i) the distance \( r \) from the Sun to the comet, (ii) the nature of the comet and (iii) the distance \( \Delta \) from the comet to the Earth. The expected brightness of a comet I, can be expressed in terms of magnitudes as

\[
m = m_0 + 5 \log \Delta + 2.5n \log r
\]

(1.1)

where \( m \) is the total apparent magnitude, \( m_0 \) is the absolute magnitude which corresponds to \( r = \Delta = 1 \) AU. The study of large number of comets has given a good idea about the variation of brightness with heliocentric distance \( r \) as well as the mean value of \( n \). The study based on photometric data for more than 200 comets (Whipple, 1991) reveals that the mean value of \( n \) lies in the range \( 2.4 < n < 5 \). Since the value of \( n \) is uncertain, the equation (2.3) can be written in a simplified form as

\[
m = 5 \log \Delta + m(r)
\]

(1.2)

where,

\[
m(r) = m_0 + 2.5n \log r
\]

From the observed light curve, the value of \( m(r) \) can be calculated from
equation (1.2) as a function of the time from the perihelion passage. Festou (1983) observed comet Crollmellin (1984IV) and calculated the expected brightness using equation (1.2). In general, the observed brightness in the visual region is mainly due to the continuum and the Swan bands of the C₂ molecule. The continuum is made up of scattering by the dust particles in the coma as well as the reflection from the nucleus. Since H₂O is the most abundant molecule in a comet, the cometary activity is basically given by the production rate of hydrogen, Q_H (Divine et al. 1986). The results for comet Bradfield (Budzien et al. 1994) indicate the dependence of the H₂O production rate with heliocentric distance as \( r^{-3.8} \) to \( r^{-1.4} \). For comet Austin 1990V, the variation is between \( r^{-1.8} \) to \( r^{-2.8} \). The study of several comets has shown a variation of the production rate of H₂O with the heliocentric distance from that of \( r^{-2} \) dependence (Despois et al. 1981). The results for the production rates of CN, C₂, C₃, CH etc. From the study of several comets, it has been suggested that even though the lines of C₂, CN and others dominate the visual spectral region, their production rates are lower by a factor of 100 or so compared to that of H₂O or H.

### 1.4.2 Spectrometry (Optical)

Spectrometric measurement is a good tool to understand the various cometary phenomenon by identifying the spectra of comets. Several transitions were
observed first in the cometary spectra before being studied in the laboratory. The observations carried out in the visual spectral region of around 3000 to 8000 Å have been the main source of information for the study of cometary atmosphere. Some of the general information regarding the main characteristic features of the spectra of comets can be obtained from the spectra of the visible region.

For heliocentric distances, \( r \geq 3 \) AU, the spectrum mainly comprises of the continuum radiation arising due to the solar radiation scattered by the dust particles present in the cometary atmosphere. As comet approaches Sun, the emission lines of the various molecules appear. The molecular bands first to appear are those of CN at \( r \sim 3 \) AU followed by the emission from C\(_3\) and CH. Thereafter, the emission from C\(_2\), OH, NH and NH\(_2\) appear in the spectrum. The spectra of comet Encke showed the Swan band sequences corresponding to \( \Delta v = -1, 0, +1 \) of the C\(_2\) molecule, whose wavelengths lie around 5635 Å, 5165 Å and 4737 Å respectively. The spectra of comet Halley taken at a spectral resolution of 0.07 Å beautifully shows the rotational structure of the (0, 0) Swan Band of the C\(_2\) molecule (Lambert et al. 1990). Since the Swan bands of the C\(_2\) molecule dominate the spectrum in the visual region, to a first approximation, it also determines the \textit{visual diameter} of the head of the comet.

The emission due to C\(_3\) molecule has a broad feature extending from 3950 to 4140 Å, with a strong peak around 4050 Å. The identification of C\(_3\) feature
in comets was difficult as the laboratory analysis was not available. Various transitions of the CN molecule, both at the red ($\lambda \sim 7800\text{Å} - 1\;\mu\text{m}$) and the violet ($\lambda \sim 3600 - 4200\text{Å}$) wavelengths have been identified. The rotational structure of CN band is well resolved (Whipple 1972). The lines of H$_2$O$^+$ ($\lambda \sim 5500 - 7500\text{Å}$) were identified for the first time in comet Kohoutek (Hupper et al. 1975). The bands of CO$^+$ around $\lambda \sim (3400 - 6300\;\text{Å})$ have been observed in many comets. The sodium D-lines at 5890 and 5896 Å, can show up for $r \leq 1.4$ AU. The \textit{in situ} mass spectrometer studies of comet Halley has given lot of new information about the species present in the coma (Huebner et al. 1991). The good quality spectra that exists for comet Halley has shown a large number of unidentified lines (Crovisier & Schloerb 1991). Some of the important conclusions drawn from the observed atomic and molecular spectra of comets (Huebner et al. 1991) Also recent spectroscopic investigation on the composition of outgassing products of comets (Bocklee-Morvan et al. 2005) mainly at radio and infrared wavelength had confirmed that the cometary ices are mainly composed of water. At closer approach to Sun the cometary activity are governed by sublimation of water. Also the grism spectroscopy of comet C/2007 N3 (Lulin) gives the production rate of OH, CS, NHCN, C$_3$ and also the water production rate (Bodewits et al. 2011). It is found that for the comet Lulin’s gas production appear to vary by 25% to 50% on time scales of the order of days.
(i) The molecules detected are composed of the most abundant elements in the Solar System, namely H, C, O and N.

(ii) Most of the species detected are organic, indicating the importance of carbon, similar to the case of interstellar molecules.

(iii) The presence of NH and NH$_2$ implies that NH$_3$ should be present.

(iv) Methane (CH$_4$) is tentatively identified.

(v) The presence of CO$_2$ in comets was inferred indirectly from the presence of CO$_2^+$. 

But the direct determination of CO$_2$ came from the Infra red observation of comet Halley. The study of the isotopic abundances in comets has attracted many investigators. Since comets contain the most abundant elements, namely H, C, N and O, do have many isotopes. Therefore a comparison of the isotopic ratios of these elements in different kinds of objects will reveal the history of the whole evolutionary process. Also the detection of several complex molecules in comets has given important information that the cometary material and the interstellar material could be very similar in nature. The study based on the isotopic ratio of $^{12}C/^{13}C$ in many comets give a value $\sim 90$ (Vanysek and Rahe, 1978; Lambert and Danks, 1983; Jaworski and Tatum, 1991; Wyckoff et al. 1993 etc.) which is same as Solar System value. The other measured isotopic ratios of $^{16}O/^{18}O \sim 450$ and $^{32}S/^{34}S \sim 22$ from in situ mass spectrometry
are also consistent with the solar values of 500 & 23 respectively (Langevin et al. 1987a; Jessberger et al. 1988 a, b). These results suggest that the cometary materials and the Solar System materials are essentially the same. Recently (Mumma et al. 2011) observed the Comet C/2007 N3 (Lulin) using U.V. grism spectroscopy provided a useful information about the production rate of $OH, CS, NH, CN, C_3, C_2$ and dust in the coma of the comet for the first time by using ultra violet optical telescope (UVOT). Further the observation on comet Tempel1 by NASA's Deep Impact mission started this type of approach.

Two similar instruments (swift-UVOT) Mason et al. 2007; and optical monitor onboard ( Schutz et al. 2006) used the rapid cadence and broad band spectral filter of UVOT to trace the development of the gaseous and ice components of comet Tempel1.

1.4.3 Polarimetry (Optical)

Cometary polarimetry has always been considered a powerful tool in the study of cometary dust. The polarimetric studies of comets can give important information about the nature and composition of the cometary particles. Comets were among the first astronomical objects recognised as polarisers of light. Arago (1855) was the first to discover the existence of polarisation in comets when visually observing the comets 1819 II and 1835 III. Wright (1881) found maximum values of $P$ to be as high as 23% and 13.8% for comets 1881 III and
1881 IV respectively, and noted rapid changes in P for both comets. The contemporary stage of polarisation investigations begin with the work of Öhman (1939, 1941). Öhman supposed two different polarisation mechanisms to act in comets: (i) polarisation by resonance fluorescence of molecules and (ii) polarisation due to scattering of sunlight by dust grains. Comets in general possess a continuum in the visible region of the spectrum. But at certain wavelengths, however, the polarisation features, are contaminated due to the polarisation present in the cometary molecular line emissions, Sen et al. (1988). As already discussed in Section 2.1, since the last apparition of comet Halley (1985-86), observers have been using a set of filters, centered at $\lambda = 0.365, 0.484, 0.684$ $\mu$m, to avoid contamination by line emission. Such filters, commonly known as IHW filters have made comparison of polarisation data of various comets easy. Linear and circular polarisation measurement of several comets have been studied by several investigators over last fifty years (Hoag 1958; Bappu & Sinhval 1960; Bappu et al. 1967; Bücher et al. 1975; Kiselev & Chernova 1978, 1981; Michalsky 1981; Bastien et al. 1986; Kikuchi et al. 1987; Le Borgne et al. 1987; Sen et al. 1991a 1991b; Chernova et al. 1993, Joshi et al. 1997; Kiselev & Velichko 1998; Ganesh et al. 1998; Manset & Bastien 2000; Ganesh et al. 2009; Hadamcik et al. 2010, 2011 etc.). Recently, the linear polarization measurement of comet NEAT C/ 2001 Q4 have been taken by Ganesh et al. 2009, through International Halley Watch (IHW) narrow band continuum and
B, V, R broad band filters and the comet 67P/Churyumov-Gerasimenko have also been taken during its 2008-2009 apparition, Hadamek et al. (2010).

The first direct evidence of grain mass distribution (Mazets et al. 1987; Lamy et al. 1987) was obtained by in-situ measurements of the comet Haley. It indicated three classes of particles. The lighter elements called ‘CHON’ (Clark et al. 1986), carbonaceous chondrites, and silicates (Mg, Si and Fe) were the essential chemical compositions of dust particles in the comet Halley. Actually, the observed linear polarisation of comets is generally a function of

1. Incident wavelength ($\lambda$)

2. Scattering angle ($\theta$) (180° - Phase angle)

3. The geometrical shape and size of the particles and

4. The composition of the dust particles in terms of complex values of refractive index $m(n - ik)$.

1972); Bennett 1970 II (Bugaenko et al. 1973; Kharitonov & Rebristy 1973); Kohoutek 1973 XII (Bugaenko et al. 1974; Noguchi et al. 1974); West 1976 VI (Kiselev & Chernova 1978); showed that, in the visual domain, the polarisation increases with increasing wavelength. The polarimetric observation of comet Halley has enriched to a very large extent our knowledge in cometary science (Bastien et al. 1986; Kikuchi et al. 1987; Le Borgne et al. 1987; Sen et al. 1991a; Chernova et al. 1993). Analysis of these polarisation data reveal the nature of the cometary grains, which include size distribution, shape and complex refractive index of cometary grains. The in-situ space craft measurement of Halley, gave us the first direct evidence of grain mass distribution (Mazets et al. 1987). Lamy et al. (1987) compared the data from various space crafts like Vega-I, Vega-II and Giotto, and arrived at grain size distributions for Halley, for various bulk densities. From the work of Mazets et al. (1987), assuming a power law size distribution, one can derive the value of complex refractive index of cometary grains, using Mie type scattering process (Mukai et al. 1987; Sen et al. 1991a). These complex refractive indices can characterise the composition of cometary grains. Also the study of several other comets like Bradfield 1987 XIII (Kikuchi et al. 1989; Chernova et al. 1993); Levy 1990 XX (Chernova et al. 1993); Austin 1990V (Chernova et al. 1993; Sen et al. 1991b), Hale-Bopp (Ganesh et al. 1998; Manset & Bastien 2000); Hyakutake (Joshi et al. 1997; Kiselev & Velichko 1998; Ganesh et al. 2009;
Sen et al. 2009; Hadamcik et al. 2010 etc.) enriched further the knowledge about the comets.

1.4.4 The Space Craft Observations

The *in situ* measurement involves the direct analysis of samples taken on board the probe, e.g., counting of particles, mass spectroscopic analysis of grains or gases, analysis of the solar wind or magnetometry. The first *in situ* measurements were carried out on comet 21/P Giacobini - Zinner (1985 XIII) by the ICE (International Cometary Explorer) Satellite on September 11, 1985 which passed through the plasma tail of comet Giacobini - Zinner. Although the spacecraft was not originally intended for a comet mission, but the space mission was successful in providing various important data. This mission gave the first and only measurements of the density and low energy distribution of the electrons (Coplan et al. 1987). The study of comet Halley in 1986 was a tremendous success for cometary science. Halley's 1986 apparition presented an ideal opportunity for cometary scientists to study it. Halley's comet was situated almost behind the sun at perihelion passage on 9 Feb 1986, and was therefore very badly placed for earth-based observation. The telescopic observations were thus best carried out before perihelion in April 1986. In order to study this famous comet thoroughly, scientists of different regions suggested space exploration of comet Halley.
Five space probes were sent to investigate comet Halley: a European probe: Giotto (named after the Italian painter Giotto di Bondone); two Soviet probes: Vega1 and Vega2 and two Japanese probes: Suisei (comet) and Sakigake (Pioneer). All the encounters took place on the sunward side of the comet. The spacecraft Giotto, which passed at a distance of approximately 600 km from the nucleus, made the closest approach to the nucleus. The spacecrafts Vega1 and Vega2 passed at a distance of around 8000 km from the nucleus. The distances of the closest approach of the Japanese probes Suisei and Sakigake were around $1.5 \times 10^5$ km and $7.6 \times 10^6$ km respectively. The ICE spacecraft also passed through at a distance of around 0.2 AU upstream of comet Halley later in March 1986. In 1992, the European probe, Giotto had been subjected to a series of tests and redirected towards a new less active comet, 26P/Grigg - Skjellerup. The name of the mission was Giotto Extended Mission (GEM) and the flyby took place on 10th July 1992. This mission also helped scientists to know more about comets.

The most direct means of determining the chemical and isotopic compositions of comet dust are the particulate Impact Analyser (PIA) by European space craft Giotto and PUMA by Soviet space craft VEGA 1 and 2 was carried which reveals that ions originate when a cometary dust particle hits a metal target of the instrument with high velocity which are then mass-separated in the reflector type time-of-flight tube and detected by an electron multiplier.
(Kissel et al. 1986a, b). From the complete analysis of in situ observation
(Kissel et al. 1986a, b; Sagdeev et al. 1986; Sole et al. 1986; Jessberger and
Kissel 1987; Jessberger et al. 1987; Brownlee et al. 1987; Mukhin et al. 1987;
Kissel and Krueger 1987a; Krueger and Kissel 1987; Jessberger et al. 1988a,
b), it was noted that some spectra are dominated by ions from the elements
H, C, N and O while in other spectra these ions were virtually absent and
instead rock forming elements Mg, Si and Fe were most abundant ions(Kissel
et al. 1986a, b). This led to the designation of ‘CHON’ particles and ‘silicates’
particles. The size of the impinging grains can be estimated from intensity
of the target ions(Ag) produced upon impact and density from the ratio of
target to projectile ions (Kissel et al. 1986a). The masses of silicate particles
range from $10^{-12}$ to $10^{-14}g$, while those of CHON grains are typically less than
$10^{-14}g$ (Sole et al. 1987 a).

The ICE spacecraft, which first passed through the tail of comet P/Giacobini
-Zimmer and last passed through Halley, gave important measurements of the
unperturbed solar wind upstream of the comet. The Giotto probe and the two
Vega probes passed very close by the comet Halley and carried out important
measurements. The three probes were provided with a camera to photograph
the nucleus and its immediate neighborhood. They also carried several mass
spectrometers to study the chemical composition of neutral gases, ions and
cometary grains etc. In addition to that Giotto probe had a photopolarime-
ter for studying optical properties of cometary dust particles. The Japanese
probes: Suisei and Sakigake, which flew by at greater distances from the comet
were designed to study the hydrogen envelope by analysis of its UV radiation
in the Lyman $\alpha$ line at 121.5 nm, and also to study the electromagnetic envi-
ronment of the comet.

The space missions to comet Halley gave direct access to study the physi-

cal and optical properties of the dust grains. The ion mass spectrometer on
board the Giotto spacecraft has provided important information about the
ions present in the coma of comet Halley to a distance of 1000 km (Huebner
et al. 1991). However the $\textit{in situ}$ detectors on board of the spacecraft best
determined the mass distribution of cometary dust particles. The spatial den-
sities at a distance of 1000 km from the nucleus of comet Halley have been
calculated by many investigators (Vaisberg et al. 1987b; Mazets et al. 1987;
Mc Donnell et al. 1987; Lamy et al. 1987). Cometary dust grains of all
sizes from $10^{-17} g$ to $10^{-3} g$ were observed by the $\textit{in situ}$ detectors. Remote,
ground-based observations on which the pre-encounter models were based, did
not allow the detection of particles smaller than about $10^{-13} g$. Tiny particles
with mass $3 \times 10^{-17} g$, or just larger, were detected by the $\textit{in situ}$ detectors in
large quantities. These particles are of sizes that are comparable to interstel-
lar dust. Impacts of very large particles with masses larger than 1 mg were
recorded only by the Giotto Spacecraft. Because of the very large sensitive
1.4.4: The Space Craft Observations

area of about $2m^2$ for detecting large particles and because of the closeness of Giotto to the nucleus of Halley, the largest single particles with a mass of about 1 mg were recorded by the DIDSY experiment (Mc Donnell et al. 1986 b). The comet Halley’s grains were found to be essentially composed of two end member particle types - a silicate and a refractory organic material (CHON) in accordance with the IR observations.

The Deep Impact mission is a partnership among the University of Maryland (UMD), the California Institute of Technology’s Jet Propulsion Laboratory (JPL) and Ball Aerospace and Technology Corp. Deep Impact is a NASA Discovery Mission, eighth in a series of low-cost, highly focused space science investigations. In January 2005, a Delta II rocket launches the combined Deep Impact spacecraft which leaves Earth’s orbit and is directed toward the comet Tempel 1 and collects images of the comet before the impact. The Deep Impact spacecraft arrives at Comet Tempel 1 to impact it with a 370-kg (820-lbs) mass. Images from cameras and a spectrometer are sent to Earth covering the approach, the impact and its aftermath. The effects of the collision with the comet will also be observable from certain locations on Earth and in some cases with smaller telescopes. The data is analyzed and combined with that of other NASA and international comet missions. Results from these missions will lead to a better understanding of both the solar system’s formation and implications of comets colliding with Earth.
A series of coordinated observations, made under ideal conditions by the world’s largest collection of big telescopes, delivered surprising new insights into the ancestry and life cycles of comets. The observations also allowed scientists to determine the mass of material blasted out by the collision. The findings are based on the composition of rocky dust detected by both the Subaru and Gemini 8-meter telescopes and ethane, water and carbon-based organic compounds revealed by the 10-meter W.M. Keck Observatory. The combined observations show a complex mix of silicates, water and organic compounds beneath the surface of the comet. These materials are similar to what is seen in another class of comets thought to reside in a distant swarm of pristine bodies called the Oort Cloud.

STARDUST is a robotic space mission launched by NASA on February 7, 1999 to collect the samples from the nucleus of the comet Wild-2. This primary mission was completed on January 15, 2006. The space craft was then retargeted to comet Tempel1 on February 15, 2011 which comet was also visited by Deep Impact on 2005. This is the first space mission to collect cosmic dust and acquire images of a previously visited comet.

The primary objective of the mission was to

1. Provide a flyby of the comet Wild-2 to collect the comet dust at a sufficiently low velocity.
2. Collect as many as high resolution images of the comet coma and nucleus as possible.

Sample returned of comet Wild-2 revealed that a wide range of organic compounds including nitrogen, aliphatic hydrocarbons with longer chain length than those observed in the diffuse interstellar medium, amorphous silicates, olivine, pyroxene, hydrous silicates and carbonate minerals were found. On February 15, 2011 star dust encountered Tempel-1. The images collected from stardust encounter of the comet Tempel-1 revealed changes in the terrain. It also identified and collect images of the crater found by Deep Impact which is about 150m in diameter (Schultz et al. 2012)

The ROSETTA space craft named after the ROSETTA stone, a famous stone that allowed ones to understand the Egyptian hieroglyphics. It is a robotic space craft mission of the European agency to study the comet 67P/Churyumov-Gerasimenko. It was launched in 2004 and would reach the comet by 2014. On the last part of the 2014, the Philae lander will attempt to land and perform detailed investigation on comet’s surface. The main objectives of the mission includes

1. Characterisation of the comet nucleus.

2. Determination of the chemical compounds present.

3. Study of comet activities and developments.
The spectroscopical investigation of the core is done by four instruments: (i) an ultraviolet imaging spectrograph (ALICE) which will search for the abundance of the noble gas in the comet core, (ii) Optical spectroscopic and Infrared Remote Imaging system (OSIRIS), (iii) Visible and Infrared thermal Imaging spectrometer (VIRTIS) which will make IR spectra of molecules of comet coma and (iv) Microwave instrument for Rosetta Orbiter (MIRO) will detect the abundance and temperature of volatile substances like water, ammonia, and carbon dioxide by its microwave emission. The space craft also contain Rosetta Orbiter Spectrometer for First and Neutral Analysis (ROSINA), Micro Imaging Dust Analysis System (MIDAS), Cometary Secondary ion Mass Analyser (COSIMA), Grani Impact Analyser and Dust Accumulator (GLADA) and Rosetta Plasma Consortium (RPC). After the successful launch of Rosetta mission 2004, Rosetta executed its close flyby of Earth in 2005. In 2007 Rosetta’s OSIRIS took various images of Mars using different photographic filters. In 2009 the space craft made a closest approach of Earth. In 2010 the observation of the dust tail of asteroid P/2010 A2 and its comparism with observation of HST confirmed that P/2010 A2 is not a comet but an asteroid. Using linear polarization observations Hadamčík et al. (2010) made a comparison between different coma regions and different comets, including comets that have been studied by space probes. Remote observations of the light scattered by comet 67P/Churyumov-Gerasimenko dust coma are of major
importance for determining the physical properties of the particles and prepare the rendezvous with the ESA/Rosetta spacecraft in 2014. Imaging polarimetric observations were conducted by Hadamcik et al. (2010) at the Haute-Provence observatory (France) on 2009 and at IUCAA Girawali observatory (India) on 2008. With the imaging technique, the intensity and linear polarization variations are studied through the various coma regions. These observations are compared to other cometary data (e.g. Jupiter family comets) and to numerical and experimental simulations. Polarization and intensity variations in the coma of 67P/Churyumov-Gerasimenko are reminiscent of those noticed for some comets such as comet 81P/Wild 2 and comet 9P/Tempel 1.

The NASA space craft DAWN was constructed with the cooperation of European countries like Germany, Italy and Netherland. The mission was launched on September 27, 2007 and DAWN reached Vesta on July 16, 2011 where it will orbit and explore Vesta upto 2012. The space craft is scheduled to reach ceres in 2015. This space craft is the first to visit the either body. Vesta and ceres are the two most massive asteroids, and they are much larger than other asteroids visited by space craft. Both have survived largely through the collisional history of the solar system and so preserve the retrieval records of physical and chemical condition during the solar systems’s early planet forming epoch. Vesta appears to be a dry differentiated body with evidence of Pyroxene-bearing lava flows. Also telescopic observation reveal mineralogical variation
across its surface. Ceres the largest body in the asteroid belt do not exhibit reflectance spectrum as shown by Vesta. Microwave observations interpreted that it is covered with a material like clay, which would indicate water played role in Ceres's history Rayman et al. (2006). The main instrument used in DAWN are

1. A framing camera (FC) contributed by Germany which uuses 20mm aperature, f/7.5 refractive optical system with a focal length of 150mm. A frame transfer CCD of 1024x1024 sensitive 93 rad pixels is placed at the focal plane of the camera which offer resolution of 17m/pixel for Vesta and 66m/pixel for Ceres.

2. Visual infrared spectrometer (VIR) is the up gradation of visible and Infrared thermal Imaging Spectrometer used in Rosetta. The spectral frames of VIR are 256x432 spectral with a slit length of 64 mrad.

3. The third instrument is Gamma Ray and Newton detector (GRaND) is used to measure the abundances of the major rock forming elements like oxygen, magnesium, aluminium, silicon, calcium, titanium and iron in Vesta and Ceres as well as platinum, uranium, and water.

The DAWN mission had provided detail about the Southern hemisphere of Vesta which boasts one of the largest mountains in the solar system. The image from DAWN revealed that a mountain, three times as high as Mt.
Everest amidst the topography in the South Polar region of giant asteroid Vesta.

EPOXI is an unmanned space mission launched by NASA using existing Deep Impact vehicle. The mission was originally targeted for the comet 85P/Boethin, but later retargeted to the comet 103P/Hartly. The main two aim of the mission was Deep Impact extended Investigation (DIXE) and Extra Solar Planet Observation and characterization (EPOCh). On November 4, 2010 EPOXI spacecraft came within 694 km of comet Hartley 2, which is about one kilometer in diameter. The EPOXI’s direct imaging of the comet Hartley 2, revealed that the comet was in the process of shedding off large amount of water. Further the mission revealed that the rate of water generation in the comet Hartley is approximately three times as observed in 1997 as compared to that in 2010. This indicate that with repeated passage of the comet through the inner solar system the comet get ‘dry up’ and become less active. The result of the mission (Kolkolova et al. 2010) can be summarized as

1. There was some near nucleus dust present even at large distance of pre perihelion. The activity level was decreased as compared to the last perihelion passage.

2. The photometric observation revealed that the comet nucleus was ≤ 1km
assuming 4% albedo.

1.5 The comets and its important role in Solar System studies

A comet is a solid body orbiting the Sun typically composed of rock, dust, or ice. According to the widely accepted current theories, comets were formed from condensed interstellar gas and dust clouds in the early stages of the creation of the universe and so comets were debris left over from the buildings of the outer most planets. The cometary material must be of interstellar origin from which the Sun and the planetary system evolved. If the comets were formed along with other Solar System bodies about 4.5 billion years ago, they would have the same composition as that of the Solar System material. Again if the comets were formed more recently, they would have a different composition reflecting the contemporary interstellar abundances. So, it is necessary to know the nature of the primordial cometary particles. The method which can give information about the possible nature of the primordial cometary materials and the time scale or the age is the study of isotopic ratios of various elements. Actually, the relative abundances of different isotopes preserve the life history of the formation process and hence help in understanding the nature of the original material. Recently most of the measurements referred
1.5: The comets and its important role in Solar System studies

The isotopic ratio $^{12}C/^{13}C$ in comets. The isotopic ratio of $^{12}C/^{13}C$ has been analysed extensively for various objects in the Solar System and in the interstellar medium. The study based on the isotopic ratio of $^{12}C/^{13}C$ in many comets give a value $\sim 90$ (Vanysek and Rahe 1978; Lambert and Danks 1983; Jaworski and Tatum 1991; Wyckoff et al. 1993 etc.) which is same as the solar system value. Other isotopic ratios were determined from in situ measurements of comet Halley and their values are roughly in accordance with the Solar value. These results suggest that the cometary materials and the Solar System materials are similar in nature. Therefore, the study of comets will give the information about the least-processed and primordial materials of original Solar nebula, from which the present day Solar System has been formed some 4.5 billion years ago.

Comets are the remainders of material formed in the coldest part of our solar system. Impacts from comets played a major role in the evolution of the Earth, primarily during its early history billions of years ago. It is also believed that they brought water and a variety of organic molecules to Earth. The study of comets is also important to know the origin of life on Earth. The standard hypothesis for the origin of life, first outlined by Oparin (1924, 1938) and Haldane (1928), begins with the biological production of organic materials. As all life on Earth is composed of organic materials, the elements C, H, N, O, S and P are believed to be essential for all living systems. Miller (1953)
did an experiment and showed that when gaseous mixture of NH₃, CH₄ and H₂O is subjected to an electric discharge, it produced several kinds of organic molecules including amino acids. This suggests that the same phenomenon has been taken place in the early stages of the Earth leading to formation of life on Earth. All the elements C, H, N, O, S and P, essential for living system, have been detected in comets (Clark et al. 1987; Langevin et al. 1987b; Jessberger et al. 1988). Other studies indicate that the early Earth’s atmosphere contained mostly CO₂, H₂O and N₂, which make it difficult for the formation of organics (Walker 1977; Pollack & Yung 1980; Levine 1985a). The existing observations show that the amount of organics in the Solar System objects seems to increase with distance from the Sun. This suggests that the organics necessary for chemical evolution are found in the outer Solar System, whereas water, an essential ingredient for the life formation, is found in the inner Solar System. This led to the suggestions that the organics might have been transferred from outer to inner regions of the Solar System by some means, possibly through comets. Thus comets may have taken important role for the formation of life on Earth.
1.6 The Objective and Layout of the present work

The objective of the present work is to study the polarisation properties of different comets. The theory of scattering of plane EM waves is basic to the study of dust grains of comets. Several scattering theories (e.g. Mie theory, T-matrix theory, Superposition T-matrix theory etc.) are used to analyse the polarimetric data of comets. Also Discrete Dipole Approximation theory is also discussed but due to high computational requirements it is not used in this work. In the present work, the distribution of intensity and the polarisation of different comets have been studied using superposition T-matrix theory. In the first phase, the polarimetric data of comet NEAT C/2001 Q4 and comet Bradfield 1987 P1 have been studied using aggregate dust model. Recent observation of cometary dust reveals that cometary dust is a mixture of compact and aggregate particles. So, a combine dust model is proposed which includes cometary dust to be a mixture of compact and porous aggregate particles to study the observed polarimetric properties of the comet Halley. Besides these the polarimetric properties of light coming from stars background to several dark clouds have been studied. Some of these clouds are undergoing star formation processes. Therefore, the polarimetric study was aimed at understanding this complex process.
1.6: The Objective and Layout of the present work

The layout of the thesis includes following chapters:

1. Introduction

2. Different light scattering theories to study the polarisation properties of comets

3. Aggregate dust model to study the polarisation properties of comets NEAT C/2001 Q4 and Bradfield 1987P1

4. Combined dust model for modeling polarisation properties of the comet 1P/Halley

5. Imaging polarimetry of star forming Bok Globule.

As already discussed, the first chapter contains an overview of Cometary Science in general. In this chapter, the basic definition of comets, its structure, classification and origin are discussed. A brief description of the nature of cometary dust is also discussed. This chapter also contain information on several methods, e.g. Photometry, Spectrometry, Polarimetry which are used in the optical region for the study of comets. Besides these, the in situ spacecraft measurement of comets is also discussed in this chapter. The comets and their important role in Solar System studies are then discussed.

The second chapter contains a brief overview of the different light scattering theories like Mie-theory, T-Matrix theory, Superposition T-Matrix theory
1.6: The Objective and Layout of the present work

and Discrete Dipole Approximation used for the polarisation measurements of cometary dusts is discussed. It is to be noted that we used T-matrix code for simulating the observed polarisation characteristics of different comets.

The third chapter contains a brief overview of aggregate dust model and its application to understand the polarisation properties of comet NEAT C/2001 Q4 and its comparison with the comet Bradfield 1987P1.

The fourth chapter will contain Combined Dust Model and its application to explain the polarisation properties of comet 1P/Halley.

The fifth chapter discussion is made on the polarisations which have been observed for stars background to several star forming clouds. The observed polarisations is interpreted in terms of the on going star forming processes in the cloud.