Abstract

Comets are considered to be able to provide key information about the origin and early evolution of our solar system, because they are believably leftover building blocks of the outer solar system formation process. Presumably, they can offer clues to the formation and evolution of solar system some 4.6 billion years ago, and thus are important for research. In complement to photometric and spectroscopic observations, linear polarization studies give some indications for the optical and physical properties of dust grains ejected by comets when they approach the Sun and also help to facilitate taxonomic classification of comets.

In a joint campaign under CEFIPRA (Indo French Centre for the Promotion of Advanced Research) funded project (in which the author worked as a research fellow), some Indian and French astronomers observed and studied a few comets (viz C/2009 P1 Garradd, 78P/Gehrels 2, C/2007 N3 (Lulin), C/2011 L4 (PANSTARRS), 290P/Jager) appearing close to Earth between 2009-2014. They were observed with the 2m telescope at IUCAA Girawali Observatory (IGO) in India and the 0.8 m telescope at Haute-Provence Observatory (OHP) in France. The observations were carried out by imaging polarimetry method, at low phase angles ($<40^\circ$), in the red and near infra-red wavelength domains. Both broadband and to avoid gaseous contaminations, narrowband cometary filters were used.

Comet C/2009 P1 (Garradd) was observed from IGO and OHP by imaging polarimetry for nearly 5 months from October 2011 to March 2012, over an intermediate phase angle range (28°-35°). Two months before perihelion and one month after, dust particles seem to be ejected all around the optocenter and jets extend to distances greater than 40,000 km. An increase of activity is noticed

in intensity and polarization after perihelion. Two and three months after perihelion the jets are mainly towards the solar direction with an extension of more than 20,000 km projected on the sky. The values of the aperture polarization are comparable to those of other comets. On the polarization maps in October 2011 and January 2012 the higher polarization zones extend in large regions perpendicularly to the solar direction where jets are also observed. In February and March 2012, the polarization in the jets is larger in the solar direction than in the surrounding coma. By its activity visible on intensity images and polarization maps at large distances from the nucleus, comet Garradd probably belongs to the high-P_{max} class of comets.

78P/Gehrels 2 was observed in three schedules- first in October, 2011 (IGO), then in January, 2012 (OHP) and lastly in February 2012 (IGO), when its phase angle was between 15.2° and 28.3°. In our knowledge, these are the first polarimetric measurements of the dust properties of Gehrels. Intensity images treated by a rotational gradient method, along with isophotes confirmed the presence of structures in the comet during the observation periods. In the polarization map, no significant difference in polarization values is noticed between the structures along anti-solar direction and the surrounding coma, which suggests similar dust properties along structures and surroundings. After perihelion, in January, some jet activity was observed along solar direction with higher positive polarization than surrounding coma. The ejected particles seem to be relatively large and present with a lower number density. The coma polarization measured in different apertures has been used to compare that obtained for other comets at similar phase angles. As expected, Gehrels is different from comet Hale-Bopp, but the comparison is not easy at phase angles $<35°$.

The overall shape of the coma of comet C/2007 N3 (Lulin), observed in March, 2009 at phase angle 35.7- 36.7° is about circular without evident jet structure. The phase curve of Lulin indicates the possibility of it to be a low-P_{max} type of comet. Comet C/2011 L4 (PANSTARRS) was observed in May, 2013 at phase angle 38-39°, and the coma of it is enlarged in the antisolar direction. Jets in a fan-like structure have been noticed between position angles 135°-245° in the treated intensity images. A correlated higher polarization region is noted on the corresponding polarization map. This, along with phase curve confirms C/2011 L4 to be a high-P_{max} type of comet. Comet 290P/Jager was observed in January, 2014 at a phase angle 14-15°. The shape of the coma is slightly elongated in the antisolar direction. Deeper negative polarization is found in the inner coma. The whole coma polarization values of the comet corresponds to the synthetic phase curve for comets at similar phase angles and wavelength.

Thus, in the present work, two Jupiter Family comets and three non-periodic Oort cloud comets have been studied. Such studies will help to find out a suitable discriminator between Jupiter Family comets and Oort cloud ones, which in turn can give a clue to the origin and evolution of solar system.

Different chapters in the thesis have been organised as follows:-

In Chapter 1, a brief account on conceptual development of cometary science has been given. Starting with the earliest notion about comet apparitions, the confirmation of their celestial nature has been narrated first. This is followed by a discussion on their trajectory, origin and the structural details. After that the importance of studying comets has been discussed. Finally, the objective and layout of the thesis has been presented.

In Chapter 2, a brief account on fundamentals of polarization theory has been

put forth. It begins with a note on history of polarization discovery and acceptance of transverse-wave nature of light (electromagnetic wave); after which, a detailed derivation of polarization theory has been given.

In Chapter 3, polarimetric technique (optical) to observe astronomical objects has been discussed. It begins with a note on early astronomical polarimetric observation and proceeds to mention some sources of astrophysical polarization. Finally, astronomical polarimetry in optical band has been described with derivation of theoretical formulae for calculation.

In Chapter 4, beginning era of polarimetric observations of comets has been cited first, followed by the modern era. After that, various features of cometary polarization, studied so far have been discussed. This includes phase angle, wavelength dependence of cometary polarization, modeling of phase curve, coma morphology, polarization map, simulation etc.

In Chapter 5, we have first introduced the comets under study and presented their log of the observations. After that, instrumental techniques and data reduction processes have been discussed in detail.

In Chapter 6, the results obtained have been presented first; which include the decreasing brightness of the light scattered by dust as a function of optocentric distance, the intensity images using some enhancement techniques, the linear polarization in terms of aperture polarization and polarization maps. After that, the results have been interpreted and based on those discussions, some conclusion have been drawn.