Polarimetric study of 8 Kreutz comets observed by STEREO

Rok Nezic (1,2,3), Stefano Bagnulo (1), Geraint H. Jones (2,3) and Galin Borisov (1,4)
(1) Armagh Observatory and Planetarium, UK (rok.nezic@armagh.ac.uk), (2) Mullard Space Science Laboratory, University College London, UK, (3) The Centre for Planetary Sciences at UCL/Birkbeck, UK, (4) Institute of Astronomy and National Astronomical Observatory, Sofia, Bulgaria

Abstract

Few Kreutz group near-Sun comets have been analysed to date – the exception is the bright comet C/2011 W3 (Lovejoy). We present analysis of eight of the brightest Kreutz group comets observed with the wide-field Lyot coronographs of the twin STEREO spacecraft. Near-Sun comets are excellent candidates for sampling a wider range of phase angles which are usually unobservable due to geometric constraints. The twin STEREO spacecraft feature a linear polariser permanently in the optical path of their two coronographs. They perform a rapid sequence of three polarimetric images with different polariser angles at least once per hour. A bespoke method for polarimetric analysis of this coronograph data, focusing on the signal of the comet and its dust tail, has been developed. It utilises known orbital properties of the comets to recombine the image triplets and produce a phase angle curve for the cometary observations. Polarisation consistently increases with distance from comet nucleus. Concerning the phase angle curve, some comets diverge significantly from the expected behaviour.

1. Introduction

1.1. Kreutz Group

Kreutz group is the largest observed group of near-Sun comets with over 2900 known members of the population [1][2], which are expected to be fragments split from a progenitor within the last 2500 years. They are characterised by sungrazing orbits with distance of perihelion \( q \approx 1 - 2R_\odot \), high inclinations \( (i \approx 144^\circ) \), and long periods [3] – see Table 1.

1.2. STEREO coronographs

The STEREO spacecraft (Solar Terrestrial Relations Observatory) mission is a pair of near-identical solar observatories launched in 2006 in heliocentric orbits lagging behind (STEREO-B) or advancing ahead (STEREO-A) of the orbit of the Earth [4]. While the mission’s main focus is the three-dimensional analysis of the solar environment, it has detected a number of near-Sun comets [2]. STEREO mission has been less prolific than the SOHO (Solar and Heliospheric Observatory) mission at discovering new comets [1], but the wide field of COR2 coronograph in the SECCHI suite of instruments, the permanent polarimeter in the light path, the relatively high cadence of full polarimetric observations (image triplets with polariser angles of 0, 120, and \( 240^\circ \)), and the relative positioning of the twin spacecraft – meaning that comets have often been observed with different geometries by both simultaneously – as well as the lack of notable cometary gas emission signatures in the coronograph bandpass (650-750 nm), make the mission better suited for polarimetric analysis of cometary dust than SOHO.

2. Methodology

The concept for the data reduction process we developed is based on – but diverges significantly from – the one used by [5], utilising a number of routines from the SolarSoft library [6]. Image triplets are analysed and recombined to determine the polarisation of the comet while excluding the background of the near-Sun enivi-
environment. Image resolution is not high enough to infer any information about variability of polarisation perpendicular to the comet head-tail line, so that data is instead integrated to provide a higher signal-to-noise ratio for polarisation along the tail.

Three-dimensional information about the comet and its tail (including the phase angle observed with spacecraft) is derived from the calculation of the cometary orbital plane from the known orbital elements of the comet. The dust tail is assumed to remain in the orbital plane of the comet. While triangulation from observations of both spacecraft (as per [5]) is possible, this method is simpler and does not require the comet to be seen from both spacecraft simultaneously.

3. Results & Conclusions

As all comets in this series are part of the Kreutz group, they are expected to have similar polarimetric properties and can therefore be compared directly and combined to produce a detailed phase angle plot – see Figure 1. Only pre-perihelion observations of comet Lovejoy are shown. Other comets do not survive the perihelion passage. The near-Sun environment produces several sources of noise that interfere with polarimetric observations of comets. These are removed to the best of our abilities, but the large scatter in Fig. 1 shows some limitations of the data.

![Figure 1: Phase curves for observations of the 8 comets from head of comet (lower Q/I) to 0.1R⊙ away along the tail (higher Q/I). A possible trend line for comet heads is shown in black.](image)

The results of the analysis show a consistent trend of increasing polarisation of cometary dust with distance from the nucleus. This trend has been observed previously [7] and shows that cometary dust is processed with time either by interaction with the solar environment or by internal collisions, affecting its polarimetric properties.

The overall shape of the phase angle curve near the comet nuclei is also of interest. We observe a negative polarisation branch at small phase angles, which is consistent with other polarimetric observations of comets [7], however we expect it to extend to 20° and see it extend to over 40° here. We also see evidence for a negative polarisation branch at high phase angles, which is not predicted by all the models of cometary dust. This may be a result of the near-Sun environment affecting the sungrazing comets in different ways than e.g. Jupiter family comets, or simply a side effect of previous lack of observations in the high phase angle regime. Notably, not all observed comets conform to the same phase angle curve.

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References