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Linear polarisation of comets observed with STEREO

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Abstract

The Lyot coronographs on the twin STEREO spacecraft observe the vicinity of the Sun in the 650-750 nm wavelength range. As well as solar physics, they have been well-utilised for comet hunting. Unlike most similar instruments, STEREO coronographs have a polariser permanently mounted in their optical path, which means full polarimetric analysis can be performed on large datasets of comet passages. Although the integration time is short and the signal is usually dominated by solar activity, polarimetric analysis of bright comets and their tails can be performed. If the geometry of the cometary encounter is favourable, a wider range of phase angles - particularly those above $90°$ - may be observed with solar-observing instruments than with other methods. We developed an improved method for polarimetric analysis of comets with known orbital elements observed with the STEREO spacecraft coronographs. The method reduces triplets of polarised images and calculates the degree of polarisation of the comet along its dust tail, with considerations of 3-D geometry, producing a phase angle curve. While most observed comets do not appear to survive the perihelion passage, a variety of polarisation properties has been observed. The method has shown to be robust and may also be extended to other solar observatories (e.g. SOHO).

1. Introduction

The STEREO spacecraft (**S**olar **Te**rrestrial **Re**lations **O**bservatory) mission is a pair of near-identical solar observatories (STEREO-A or Ahead and STEREO-B or Behind) launched in 2006 in heliocentric orbits lagging behind (STEREO-B) or advancing ahead (STEREO-A) of the orbit of the Earth. While its main focus is the 3-D analysis of the solar environment, the mission - like the earlier SOHO (**So**lar and **H**eliospheric **O**bservatory) mission [1] - has been successful at detecting near-Sun comets [4].

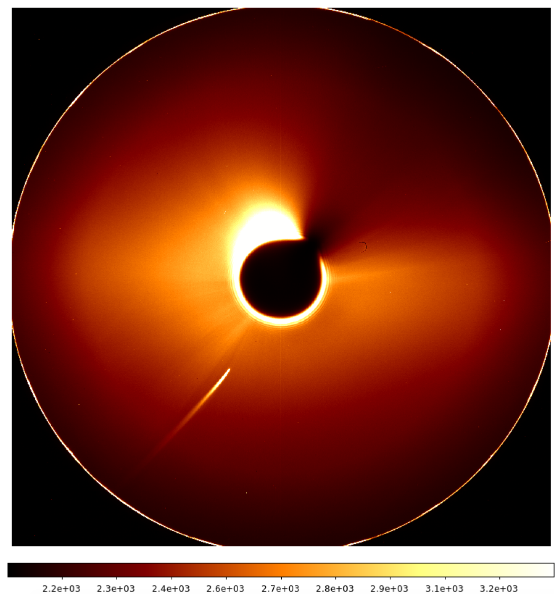

Figure 1: Comet C/2011 W3 (Lovejoy) as observed by STEREO-A/SECCHI/COR2 on 15th December 2011.

The most useful comet-hunting instruments aboard STEREO are in the SECCHI (**S**un-**E**arth **C**onnection **C**oronal and **H**eliospheric **I**nvestigation) suite of telescopes, which include two Lyot coronographs: COR1 (field of view $1.3 - 4.0R_{\odot}$) and COR2 (field of view $2 - 15R_{\odot}$) [3]. While SOHO has been more prolific in its discoveries of new comets than any other mission, including STEREO [1], the great advantage of the latter over the former is that the COR1 and COR2 instruments boast a rotatable polariser permanently positioned in their optical path. This allows for near-continuous polarimetric observations, which is particularly useful when observing the swiftly-moving near-perihelion comets. Another unique advantage of the STEREO mission is the relative positioning of the twin spacecraft (prior to 2014, when contact with STEREO-B was lost), meaning that comets have often been observed by both simultaneously. This not only increases the amount of available data, but often also the range of observed phase angles.

The polariser angles for COR1 and COR2 coronographs are 0, 120, and 240°. They both observe within the wavelength passband of 650-750 nm, which excludes the dimmer comets when compared to SOHO. Stokes Q and U, as well as the degree of polarisation P, can be computed from these three orientations.

2. Methodology

The data reduction process we developed is similar on the one used by [5], with significant adaptations and generalisations, and using some routines from the SolarSoft library [2].

Notably, while [5] required the comet to be visible in both spacecrafts' fields of view to triangulate the three-dimensional position of the comet and its tail, a simplifying assumption allows the extraction of all relevant data from a single spacecraft with minimal loss of accuracy. Using either the calculated orbital elements or the vector products of multiple heliocentric positions of the comet, the normal to the cometary orbital plane can be determined. Assuming the dust tail remains in the orbital plane of the comet and using the position information of the spacecraft, we can project every point in a STEREO image to the cometary orbital plane and thus obtain the full three-dimensional information about it.

A triplet of images in each of the polarising angles is taken in rapid succession every hour, or more frequently in some early observations. These triplets are analysed and recombined to determine the polarisation of the comet (see Figure 1 for an example raw image).

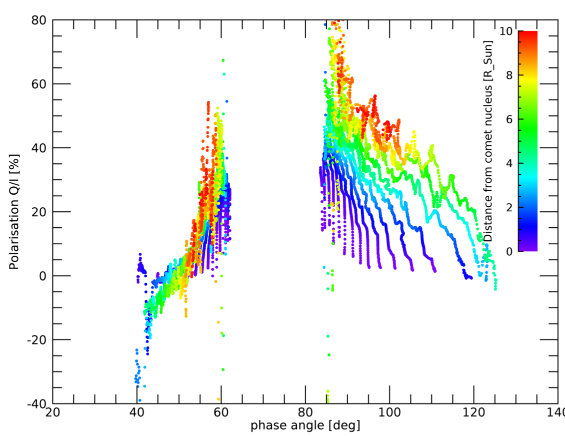

Figure 2: Phase curve of Comet C/2011 W3 (Lovejoy) during its December 2011 perihelion.

3. Results and Conclusions

To prove the accuracy of the new method, we first analysed the observations of comet C/2011 W3 (Lovejoy) and compared our results with [5], showing good agreement (see Figure 2 and compare it to Figure 9 within [5]). We then narrowed down a list of over 30 comets observed with COR2 to those bright enough for meaningful analysis. Results of this analysis will be presented here. They show our method can successfully reduce the STEREO images and provide us with polarimetric information on the comet, given a high enough signal-to-noise ratio. Phase curves can be plotted and compared to the literature, and variation of polarisation along the comet tail analysed.

STEREO-A and B spacecraft have a number of advantages which make them good candidates for polarimetric analysis of comets. Although only bright comets make good STEREO candidates, observations from STEREO and other solar observatories, for which our method can be adapted, can help expand our knowledge of polarisation of comets, and therefore of origin and evolution of comets at large.

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