CSI 769/ASTR769 Spring 2008
Solar and Heliospheric Physics

Project 2: Tracking CME Initiation and Propagation and the Modeling

Assignment date: Apr. 03, 2008
Due date for Phase 1: Apr. 17, 2008
Due date for Phase 2: May 01, 2008

1. Introduction

Two of the key questions in solar physics and space weather sciences are (1) initiation mechanism of CMEs, and (3) propagation of CMEs in the interplanetary space. The twin STEREO SECCHI instruments have provided unprecedented observations of CMEs over a large continuous distance from the surface of the Sun into the deep heliosphere from two vantage points. In this project, you are required to make full use of SECCHI stereo observations to develop models of CME initiation and propagation.

2. **Requirements**

The project is divided into two phases. Phase 1 is on the observational study of CME initiation and propagation, and the accompanied expansion. Phase 2 is on the theoretical modeling of the CME dynamic evolution. In this phase, you have two options to carry out the modeling work: one option is to focus on CME initiation, and the second option is on CME propagation.

2.1 Phase 1: observations

2.1.1. Event selection.

Find one of the best observed CME events. The angular width in COR2 shall be larger than 40 deg. The surface source region on the Sun must be visible from at least one of the two spacecraft. One starting point of searching the events is the GMU SEEDS catalog on CMEs seen by SECCHI/COR2 and LASCO/C2
(at http://spaceweather.gmu.edu/seeds/). Feel free to choose your favorite event.

If you choose to model the CME initiation, make sure that the event was accompanied by an X-ray flare recorded by the Earth-bound GOES satellite. Further, make sure that the CME is also well observed by SECCHI/COR1 and EUVI instrument; these observations are critical in revealing the early initiation. Recommended events include 2008/01/02 (~ B1 flare), 2008/03/25 (~ C2 flare), 2007/12/31 (~ C9 flare). A COR1 event catalog is available at http://cor1.gsfc.nasa.gov/catalog/.

In you choose to model CME propagation, make sure that the event was well observed by SECCHI/HI. The recommended events include 2007/10/08, 2008/03/25. A HI-1 event catalog is available at http://www.stereo.rl.ac.uk/science/events/HI_Event_list.html

2.1.2 Measurement

(1) For each selected event, first review the event as comprehensive as possible. Describe the surface source region as seen in MDI, EIT and EUVI, describe the changes as seen in COR1, COR2, HI-1, and HI-2 if appropriate

(2) Secondly, make the careful measurement of the CME as seen in COR1 (both A & B), COR2 (both A & B), and HI-1 (A or B). Assuming the CME is outlined by a perfect circle (to the first order of approximation), measure the position of the center of the circle and the radial size of the circle. The CME leading position shall be the sum of the center position and the radial size of the circle. For your convenience, I provide one example measurement routine (“cme_edge_pick.pro”) (attached), and one example circle fitting routine (“fit_circle.pro”). Using the header files of the FITS images, you should be able to convert the pixel scale from the measurement to the scale of solar radius. By combining the measurement in all snapshot images, get the Height-Time (H-T) plots for (a) the center, (b) the size of the circle and (3) the leading edge.

(3) Derive the velocity and acceleration of the CME, for both propagation and expansion. The propagation speed (acceleration) of the CME shall be the speed (acceleration) of the center of the circle. The expansion speed (acceleration) of the CME shall be the change of the radial size of the circle. The speed of the leading edge is the sum of the two. You can experiment with the functional polynomial fitting of the H-T time data to obtain velocity and acceleration. However, t o study the detailed kinematic and infer the dynamics, you need to use piece-wise fitting to obtain the velocity and acceleration from local neighboring points: the first derivative and the second derivative of the H-T data. I provide one example fitting routine (“calcu_vel_acc.pro”) for your reference.

(4) Obtain the 3-D position, velocity and acceleration of the CME. With the measurement of the center of the CME, (X_A, Y_A) and (X-B, Y_B), assuming the center is the common 3-D point as you see from both A & B spacecraft, you can convert them into the 3-D position (X, Y, Z). You may need the following procedures from SSW to perform the conversion: “scc_triangulate.pro”, “wcs_get_coord.pro”, “fitshead2wcs.pro”.

(5) If the CME is associated with a flare, (a) compare the CME velocity profiles with the GOES X-ray profile, and (b) compare the CME acceleration profile with the first derivative of the GOES X-ray profile

2.1.3 Report

For reporting the results of the phase-1 project, describe your work and the findings from the studies outlined above. You need to at least turn in the H-T data file, and the plots of H-T (A & B, 3-D), the velocity (A & B, and 3-D) for both propagation and expansion, and the accelerations.

2.2 Phase 2: theoretical modeling

2.1.1 Option 1: CME initiation and acceleration.

Use the flux rope model developed by Chen et al to fit the measured data, for the purpose of understanding CME initiation and acceleration. Try to fit both propagation (Z) and the expansion (a).

The reference to Chen's in-class presentation is available at http://solar.gmu.edu/teaching/2008_CSI769/lect05/. Recommended papars are

* Chen, Theory of Prominence Eruption and Propagation, JGR, 101, 27499, 1996.
* Chen, et al., Magnetic Geometry and Dynamics of the Fast Coronal Mass Ejection of 1997 Sept 9, ApJ, 533, 481, 2000.
* Chen, et al., The Flux-Rope Scaling of the Acceleration of Coronal Mass Ejections and Eruptive Prominences, ApJ, 649, 452, 2006.

2.1.2 Option 2: CME propagation

Use the melon-seed-overpressure-expansion (MSOE) model to fit the CME propagation. The goal is to obtain the dragging coefficient of the solar wind.

The reference is: Sisco, Crooker & Elliott, "Initial-Condition Influences on CME Expansion and Propagation", Solar Physics, Vol. 239, P. 293-316, 2006.

2.1.3 Report

For the report of the Phase-2, (1) briefly discuss the model you used, give the essential formula, (2) describe and provide the numerical procedures you developed (or obtained), (3) the results of the fitting, (4) discussion on the results, including how effective is the fitting, the limitation of the model and the possible improvement in the future.