Observations of the Inner Heliosphere During the STEREO Superior Conjunction

Team Leader: Liz Jensen (PSI, USA).
Collaborators: Tim Howard (SwRI, USA); Mario Bisi; Jackie Davies; Richard Harrison (RAL, UK); Amanda Kepley (NRAO, USA); Carl Heiles (UC-Berkeley, USA).

ABSTRACT.
We propose to take advantage of the STEREO superior conjunction to make radio Faraday rotation (FR) measurements of the corona, solar wind, and transient activity at no cost to STEREO. The STEREO conjunction offers us a unique opportunity to study the FR from an artificial source (stable, narrow band) that is moving slowly across the sky affected solely by the solar-wind outflow from the Sun. Such an opportunity has never occurred before and will likely not happen again until STEREO's return to this position ~20 years from now. We will use the Green Bank radio telescope to receive the unused, but still transmitted, polarized STEREO signal in a series of observational campaigns during the months leading up to and following the conjunction. We do not require any resources from STEREO for this campaign and do not require any deviation from the mission: everything we need is already being periodically transmitted by the spacecraft.

1. INTRODUCTION.

We propose to measure the STEREO transmission signal using the Green Bank radio telescope for the purposes of Faraday rotation (FR) diagnostics of the coronal magnetic field. This will be conducted in a series of observational campaigns as the two spacecraft approach and move from conjunction. We will receive the opposite polarization radio transmission from each STEREO spacecraft: this signal is leaked routinely by STEREO but is not measured by its standard ground stations. Our work therefore not only requires no adjustment of the STEREO mission, but also takes advantage of a currently-unused product of the STEREO spacecraft.

1.1. WHY STEREO AND WHY NOW?

Measurements of FR are most-reliably obtained from artificial signals, since we are confident that the signal we receive will be stable and we know everything about the source. Previous measurements have been made with artificial signals in the past (*e.g.* Levy *et al*., 1969; Paetzold *et al*., 1987; Jensen and Russell, 2007; Jensen *et al*., 2013), but we have been limited in our diagnostic capabilities since the sources moved quickly across the sky. STEREO offers us the unique opportunity to apply our techniques on two artificial sources that move slowly through the sky, thereby enabling long-term Eulerian analysis that we have been unable to conduct in the past, and will likely not be able to obtain again.

1.2. WHY FARADAY ROTATION?

Faraday rotation is the rotation of the plane of polarization of a polarized electromagnetic signal, caused by the signal's passage through circularly birefringent magnetized medium (in this case, the plasma of the solar-wind). The rotation angle is governed by the distance of the medium traversed by the signal, its density, and its magnetic-field magnitude and direction relative to the line of sight. With information on size and density obtained from auxiliary data sources (*e.g.* white-light imagers such as those on the STEREO spacecraft themselves), we can use FR to measure the intrinsic magnetic field of the solar wind and transient phenomena (*i.e.* Jensen and Russell, 2009). The implication is that FR provides a means by which the intrinsic magnetic field of phenomena such as coronal mass ejections (CMEs) can be remotely measured. The potential for CME evolution studies and for space-weather prediction are obvious, as is the value that such measurements would add to our ability to interpret the STEREO white-light imagery.

2. WHAT WE NEED.

We will measure both circularly-polarized components of the STEREO transmission signals using the Green Bank telescope. This strongly circularly polarized signal (with a weak linear-polarization component) is already transmitted by both STEREO spacecraft as a consequence of their antenna design; however, standard STEREO ground stations do not receive the leaked polarization. We therefore require nothing from STEREO that it is not already doing. All we will need are the details of the signal's frequency and transmission times so that Green Bank can lock in on it. Permission to receive the signal during the months leading up to, and following, the STEREO conjunction would support our request for Green Bank's highly-competitive observing time. Given the estimated dates of conjunction of March 2015, we would conduct our observational campaigns from around September 2014 to September 2015.

3. OUR OBSERVATION CAMPAIGNS.

From Nov 2014 to Nov 2015, the two STEREO spacecraft will be in superior conjunction (within 20 solar radii of the Sun). The STEREO-A spacecraft will observe the same region of space over a fraction of a solar rotation allowing limited time varying observations of the region; its offset distance changes roughly by one solar radii over the period of seven days. From February to April 2015, the two spacecraft will be on the same side of the Sun observing at different solar offsets allowing time and space varying observations, a unique opportunity to deconvolve the special structure and evolution of solar wind magnetic-field structures. Because the conjunction time period lasts for 10 months, there is a significant probability of CMEs or MHD waves crossing the lines of sight from the Earth to both STEREO spacecraft.

4. WHAT WE EXPECT TO PRODUCE.

During the May 2013 MESSENGER superior conjunction, a CME crossed the line of sight allowing the measurement of its North (RH)/South (LH) oriented magnetic-field. The results for this are currently in preparation by Jensen for submission to Science. While this demonstrated the utility of spacecraft superior conjunction data, the degeneracy in handedness versus polarity of axis orientation continued to illustrate the need for another line of sight through the magnetic flux rope of the CME. A FR experiment using the STEREO spacecraft enables us to accurately test the feasibility of

the advance warning capabilities of this technique and provides a stable "laboratory" environment for the development, testing, and validation of a variety of solar-wind and CME diagnostic tools. Finally, FR fluctuation measurements of spatially-coherent MHD waves have already been used to study the net wave efflux energy of the solar corona, a suspected source of coronal heating (Jensen and Russell, 2009).

5. REFERENCES.

Jensen, Elizabeth A.; Russell, Christopher T. (2007) Solar Physics and Space Weather Instrumentation II. Edited by Fineschi, Silvano; Viereck, Rodney A. Proceedings of the SPIE, Volume 6689, article id. 668910, 7 pp.

Jensen, E. A.; Russell, C. T. (2009) Geophysical Research Letters, Volume 36, Issue 5, CiteID L05104.

Jensen, Elizabeth A.; Bisi, Mario M.; Breen, Andrew R.; Heiles, Carl; Minter, Toney; Vilas, Faith (2013) Solar Physics, Volume 285, Issue 1-2, pp. 83-95.

Patzold, M.; Bird, M. K.; Volland, H.; Levy, G. S.; Seidel, B. L.; Stelzried, C. T. (1987) Solar Physics (ISSN 0038-0938), vol. 109, no. 1, 1987, p. 91-105.

Levy, G. S.; Sato, T.; Seidel, B. L.; Stelzried, C. T.; Ohlson, J. E.; Rusch, W. V. T. (1969) Science, Volume 166, Issue 3905, pp. 596-598.