Input to mid-term assessment of the 2013 Solar and Space Physics Decadal Survey

On the need for full-disk solar magnetographs in space around the Sun

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The Sun is fundamentally a magnetized astronomical object whose magnetic cycle and magnetic explosions our technological society must understand and anticipate. SOHO/MDI full-disk magnetograms became soon after launch in 1995 a facility-class data product that provided all other instruments onboard the magnetic context of their observations. Because of the continuous coverage and consistent quality of the magnetograph data, it quickly became the source of magnetic context for many other solar space missions and ground-based observations. This unanticipated success demonstrated the need for full-disk magnetographs in follow-up missions as shown by NASA’s ongoing (since 2010) Heliophysics flagship solar mission SDO that includes the HMI full-disk vector magnetograph. Vector magnetograms from Hinode have unveiled the importance of such measurements at even higher spatial resolution for understanding the Sun’s magnetic activity at the smallest scales. NASA’s ongoing (since 2006) STEREO mission has demonstrated the benefits of observations combining multiple lines-of-sights (LOSs). But only with the advent of Solar Orbiter (launch in February 2020) will we obtain the first magnetograms taken away from the Earth-Sun LOS, albeit only during intermittent observing times.

It is important to emphasize that SOHO/MDI and SDO/HMI each took about a decade from funding commitment to the start of observations. The time from funding commitment to launch for any future such full-disk magnetograph mission will likely not be shorter. SDO is now approaching ten years in orbit. While SOHO is still functioning at 24 years (with the MDI instrument not being used for magnetograms since 2011), such an extended operational lifetime is still rare. We will be fortunate if HMI continues to operate for another ten years. It is now high time for planning and committing funding for a full-disk solar vector magnetograph in space that will match or exceed the magnetic sensitivity, spatial resolution, and cadence of HMI.

Despite its intrinsic difficulty, there is a pressing need to measure and track over an 11-year sunspot cycle the evolving distributed vector magnetic field over the entire 4π of the Sun’s surface. Without these measurements, our knowledge of the magnetized state of the Sun will remain limited. The 2013 Solar and Space Physics Decadal Survey (DS) recognized this need and recommended magnetic field measurements (magnetograms) for a mission to the Earth-trailing Lagrange point L5 and a Solar Polar Orbiter. The DS also explicitly recommends continued space-based solar magnetic field measurements from the Earth-Sun LOS. The scientific interest and the practical (space weather forecasting) benefits of
using three LOSs to capture the current magnetic state of the Sun have been explained in recent papers by Weinzierl et al. (2016; ApJ, 828, 102), Petrie et al. (2018; So. Ph., 293, 88), and Gibson et al. (2018; Frontiers in Astr. and Sp. Sciences, 5, 32). These works demonstrate that the community support for this idea has continued to grow since the publication of the Survey.

Because the ground-based full-disk magnetograms from GONG can give only weather-dependent coverage of the Earth-Sun LOS, the continuous perfect-seeing views from gravitationally stable locations as offered by the Lagrange points remains unparalleled. Priority 2.2 of the 2013 DS asked for continuous magnetic field information, and Priority 2.3 requested evaluation of new observing locations in the context of re-charting the Space Weather Program. These priorities also appear broadly speaking in Space Weather Action Plans published by present and past Administrations. However, no progress in defining magnetic observations from these complementary locations has occurred over the past five years. With this white paper, we urge NASA to prioritize full-disk magnetography missions that fully exploit this capability.

A great advance in understanding and forecasting the Sun’s magnetic cycle and major magnetic explosions would be achieved if the global distribution and evolution of the magnetic field were observed for at least a decade from multiple complementary viewpoints by full-disk vector magnetographs at least comparable to HMI in resolution, sensitivity, and cadence. Full-disk magnetographs of various levels of performance – preferably vector magnetographs – should be included on future observing platforms for operational space weather forecasting. But first, to learn how the solar magnetic cycle and major solar magnetic explosions work well enough to reliably predict them, research-level full-disk vector magnetographs should be sent to a few select locations, such as L5, Earth space, and a polar orbit.