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Coronal disturbances and their effects on the dynamics of the heliosphere

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Abstract

The Sun blows out the solar wind which propagates into the interplanetary medium and forms the heliosphere about 100 AU across. The solar activity causes various types of time-dependent phenomena in the solar wind from long-lived corotating interaction regions to shorter on duration but more extreme events like coronal mass ejections. As these structures propagate outward from the Sun, they evolve and interact with each other and the ambient solar wind. Voyager 1 and 2 provided first unique in-situ measurements of these structures in the outer heliosphere. In particular, Voyager observations in the heliosheath, the outermost region of the heliosphere, showed highly variable plasma flows indicating effects of solar variations extending from the Sun to the heliosphere boundaries. Most surprisingly, Voyager 1 data shows shocks and pressure waves beyond the heliosphere in the interstellar medium. Important questions for the future Interstellar Probe mission are (1) how do the heliosphere boundaries respond to solar variations? (2) how do disturbances evolve in the heliosheath? and (3) how far does the Sun influence extend into the interstellar medium? This talk will review observations and recent modeling efforts demonstrating highly variable and dynamic nature of the global heliosphere in response to disturbances originated in the Sun‘s atmosphere.

1. Introduction

Numerous observations show that the solar wind exhibits variations on different time and spatial scales. This includes the 11-year solar cycle variations, large-scale structures such as interplanetary coronal mass ejections (CMEs) and merged interaction regions (MIRs; Burlaga et al. 1993) usually occurring during solar maximum; corotating interaction regions (CIRs) formed at the declining phase of solar activity (Burlaga et al. 1997); and shocks associated with CMEs and CIRs (Wang & Richardson 2002). These structures generate significant changes in the solar wind parameters, affect acceleration and transport of energetic particles in the heliosphere. The primary goal is to understand the evolution of these structures in the heliosphere, their interaction with the heliosphere boundaries and propagation beyond to the interstellar medium.

2. Observations

Measurements showed that during the 11-year solar cycle the solar wind ram pressure (ρV^2 where ρ is density and V is speed) changes by factor of 2 from solar minimum to maximum. Long-lived CIR structures are characterized by an enhanced magnetic field, plasma density, and pressure, and are bounded by a pair of shocks. Observations of CIRs by Voyager 2 and Pioneer 10 in the inner heliosphere within 10 AU showed that the ram pressure in CIRs may increase by factor of 15-30. At larger heliospheric distances, CIRs expand and merge to form CMIRs. One would expect that these structures propagate further to the heliosheath and beyond into the local ISM. In fact, Voyager 1 magnetic field data from the local ISM reveals an interval (2014.6-2015.4) with 28 day oscillations in magnetic field (Burlaga et al. 2016) indicating possible relation with CIRs. This suggest that the Sun influences this region however the origin of these oscillations are not fully understood.

By now Voyager 1 have traveled 25 AU passed the heliopause (HP). A remarkable discovery made by Voyager 1 was observation of shock waves in the very local interstellar space. These shocks are driven by solar transients that propagate to the interstellar medium.

The first shock in the VLISM was observed by V1 at the end of 2012. The important property of the VLISM shock is its very smooth nature and very large width, being about 10^4 times broader than a shock with similar properties at 1 AU. The shock properties in VLISM are dramatically different from ones inside the heliosphere.

3. Modeling

The models demonstrated that the termination shock (TS) and HP oscillate in response to varying solar wind pressure in the solar cycle (Izmodenov et al. 2008; Pogorelov et al. 2009; Provornikova et al. 2014). The boundaries of the heliosheath are constantly in motion. While time-dependent models of global heliosphere can partially explain behavior of plasma in the heliosheath observed on Voyager 2, they fail to explain plasma flows observed at Voyager 1.

Interaction of the TS with various interplanetary disturbances from upstream was studied by many authors (Provornikova et al. (2013) and references therein). The models are focused on the propagation of solar wind shock waves, contact discontinuities, forward-reverse shock pairs, and pressure pulses through the TS to the heliosheath. Simulations suggest that interaction of shocks with the TS generates several discontinuities and waves in the heliosheath. Locally TS may change its location and become weaker. Interaction of shocks with the HP produces magnetosonic waves that are reflected and trapped in the heliosheath.

Modeling of propagation of solar disturbances to the outer heliosphere presents several challenges. High resolution simulations with low numerical diffusion are required to capture the interaction of solar wind structures with heliospheric boundaries. Also the pressure in the heliosheath is dominated by non-thermal particles which strongly affects evolution of discontinuities but currently not described by the time-dependent models. Studies of 11-year solar cycle effects require knowledge of time and latitude dependence of the solar wind close to the Sun (Katushkina et al. 2013).

4. Summary

Despite of the great progress that has been done in the recent three decades in understanding variability of the global heliosphere and its relation with the solar activity, the complete picture is not achieved yet. Several questions are still unanswered: (1) how do the heliosphere boundaries respond to solar variations? (2) how do disturbances evolve in the heliosheath? (3) how far does the Sun influence extend into the interstellar medium? Advanced instrumentation and new observations on the Interstellar Probe mission will bring a closure to these questions.

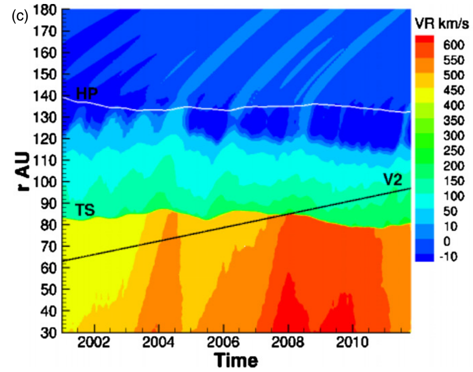

Figure 1: Modeling of TS and HP responses to the solar wind fluctuations. From Provornikova et al. (2014)

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References

[1] Burlaga, L. F. 1983, JGR, 88, 6085

[2] Burlaga, L. F., Ness, N. F., & Belcher, J. W. 1997, JGR, 102, 4661

[3] Wang, C., & Richardson, J. D. 2002, GRL, 29, 22

[4] Burlaga, L. F. & Ness, N.F., 2016, ApJ, 829, 134

[5] Izmodenov, V., Malama, Y. G., & Ruderman, M. S. 2008, Adv. Space. Res., 41, 318

[6] Pogorelov, N. V., Borovikov, S. N., Zank, G. P., & Ogino, T. 2009, ApJ, 696, 1478

[7] Provornikova, E., Opher, M., Izmodenov, V., Richardson, J., Toth, G. 2014, ApJ, 794, 29

[8] Provornikova, E., Opher, M., Izmodenov, V., Toth, G., 2013, A&A 552, A99

[9] Katushkina, O. A., Izmodenov, V. V., Quemerais, E., & Sokol, J. M. 2013, JGR, 118, 2800