The Formation of the Slow Solar Wind and the Ground State Space Weather

Nicholeen Viall (NASA/GSFC)

Angelos Vourlidas, Larry Kepko, Spiro Antiochos, Justin Kasper, and Sue Lepri
Structures in Solar Wind Density Drive Dynamics in Earth’s Magnetosphere

Cyclic SW structures, created as the slow solar wind is formed, directly drive ULF waves, affect radiation belt particles
90-minute and 20-minute Variations in Solar Wind at L1 and in Earth’s Magnetosphere

- 90-minute quasiperiodic density structures at L1/Wind
- Contains embedded 20-minute quasiperiodic density structures
- The SW drives oscillations in the magnetosphere at the exact same two periodicities (ULF waves)

Kepko et al 2002
The Solar Wind is Highly Variable Immediately After its Formation

Viall et al 2010
White light coronagraph/imagers from STEREO/SECCHI
White light = solar wind density
Density Structures in the Slow Solar Wind are Periodic

- Zoom-in and look at a series of still images beyond trans sonic point
- Shows small-scale density structures continually emitted
- Regular, periodic train of density enhancements
- Smaller periodic density structures (~1000 Mm) are embedded within larger ones

Viall et al. 2010
Periodic Density Structures are Formed at or Below 2.5 Solar Radii

COR 2 Images Jan 20, 2008

Viall & Vourlidas 2015
Density Structures in the Slow Solar Wind are (quasi) Periodic

- Time series of density in a slit of pixels at 15 solar radii
- The periodic structures all pass through these pixels as they enter the field of view and advect outwards. Like being ‘in situ’ S/C
- Though not a ‘wave’, the periodic nature confirmed in spectral analysis (Thomson 1982; Mann & Lees 1996; Viall et al. 2008)
- Periodic nature useful to distinguish from random fluctuations/turbulence
- Periodicity important information on physics of their formation
Periodic Density Structures Associated with Streamers

- 24-hr time series at every pixel - spectral test for discrete frequencies; showing frequency map for one day and median image for same day
- Frequency map: white = periodic density structures; black = no discrete frequencies
- All concentrations of periodic density structures associated with streamers; not all streamers produce concentrations of periodic density structures on a given day
Periodic Density Structures Occur with a Characteristic Timescale of ~90 minutes

White: discrete frequency in that band; Black: no discrete frequencies

Viall & Vourlidas 2015
Next up: *In situ* observations give us more clues about the formation/source of the structures
COR2 – 90 minutes ‘blobs’ at Helmet Streamers


90-minute structures with ACE high cadence data confirms solar source

Kepko et al 2016
Coronal variability drives space weather even on ‘quiet’ days

Current observational gap
Structures in the solar wind are the medium through which CMEs and SEPs propagate. Transport boundaries are observed: ‘dropouts’ of solar energetic particles. Observation of H-FE ions versus arrival time for 9 Jan 1999 SEP event. Theoretical model-based trapped magnetic field lines. Mazur et al 2000.
‘Small Things Can do Big Damage’

Small Blackholes

Small Dogs

Small Kids

Small Carpenter Ants

Small Hail

Small leaks

‘Small’ Structures from the Sun-which are constantly emitted-can have big, cumulative, impacts on Earth (terrestrial planets in general)
There is no such thing as ‘the steady solar wind’

• The observations at the HCS ‘preclude a single, wavey current sheet interpretation’. They interpreted the observations as ‘small-scale, intertwined flux ropes’

Figure 6. View toward the Sun of the plasma sheet region as distended, intertwined flux tubes forming planar magnetic structure at the sector boundary. Letters a-d reference the cross-sectional view in Figure 5.

Crooker et al. 1996
There is no such thing as ‘the steady solar wind’

Solar wind structures 100s of Mm – i.e. even on scales much smaller than CMEs CIRs - come from the Sun (see also work by Joe B.) and directly drive magnetosphere dynamics. Periodicities around 90 minutes at HCS.

Where do the shorter SW periodicities (Viall et al 2008;2009) in the ULF range come from?

Already pushing the measurements (composition and imaging) temporal resolution. We need PSP, SO, and a high resolution solar wind white light imager. Preliminary evidence says yes.
a) Periodic density structure in the proton and alpha time series

b) Detrended time series to identify more clearly the 30-minute periodicity - they are in anti-phase

c) B field rotations are often correlated with composition boundaries, but not in a predictable way.

L1 Wind Alpha Data Show 30-minute/850 Mm Structures Created in Corona

February 14th, 1996
Fourier Analysis is a useful tool to identify characteristic scale sizes. Viall et al. (2009, Geophysical Research Letters) found that the solar wind plasma source is changing in a periodic nature, creating 30-minute (850 Mm) structures.
DeForest et al. COR2 Deep Field Exposures Show Solar Wind Structures Down to the Resolution Limit for the First Time

• ApJ- responding to reviewers and submitting shortly!
DeForest et al. COR2 Deep Field Exposures Show Solar Wind Structures Down to the Resolution Limit for the First Time ...

Including an event of density structures released with a characteristic 20-minute timescale