Investigating the relation between the measured solar wind speed and the extrapolated magnetic field configuration in the solar corona

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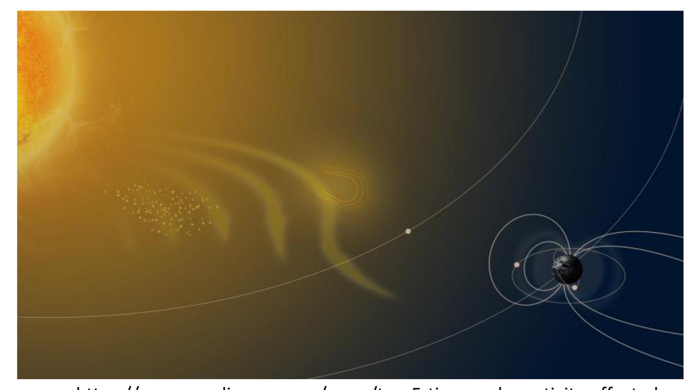
Challenge: to characterize the evolution of the solar wind within the acceleration region.

Importance:

- It gives us a better understanding of the physics of the solar corona
- Solar wind evolution is a key component for successful space weather forecast



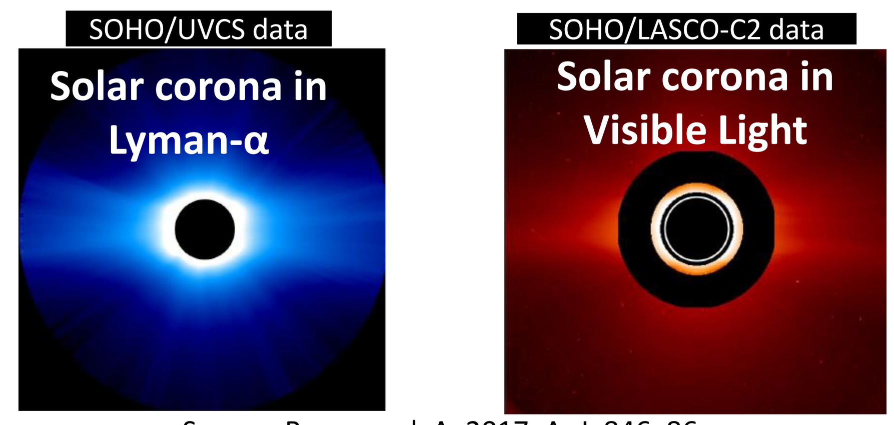
source: https://www.nesdis.noaa.gov/news/top-5-times-solar-activity-affected-earth

Solar wind measurements

Measurements of the **solar wind outflow velocity** below 10 solar radii are possible only by means of remote sensing observations. One of the methods applied to such data to derive the radial speed of the solar wind is the **Doppler dimming technique** (Withbroe+ 1982, Noci+ 1987). It exploits the Doppler shift observable on intensities and profiles in UV/EUV spectral lines whose emission is due to resonant scattering of chromospheric light to measure the radial component of the solar wind speed. The intensity of the coronal emission is in fact related with the relative velocity between the atoms emitting the exciting radiation and the atoms absorbing the radiation that, as a consequence, undergo transition into an excited state followed by spontaneous emission: if the speed of the atoms is nonzero, then the chromospheric emission is Doppler shifted in the spectrum, reducing the value of the convolution integral between the emission and absorption line profile.

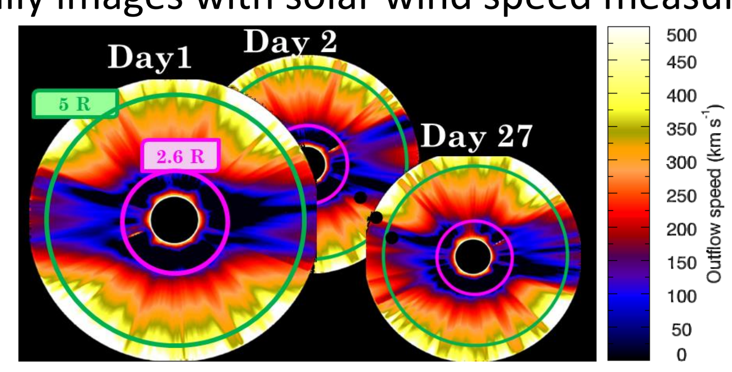
Instruments such as UVCS/SOHO and Metis/SolO give the possibility of applying this technique by using observations of the solar corona in the Lyman-α line (121.6 nm) coupled with coronagraphic observations in polarized visible light to create **2D images of the speed** projected into the POS.

By extrapolating circular profiles in images of solar wind measurements it is possible to generate **solar wind speed synoptics maps** covering different Carrington rotations for different heliocentric altitudes.

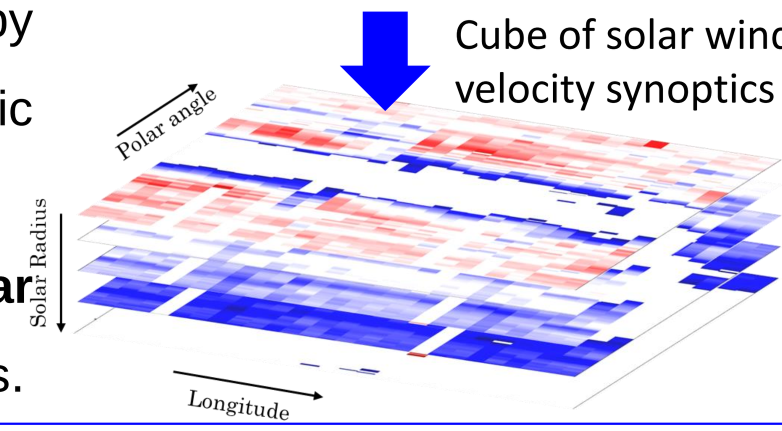


Source: Bemporad, A. 2017, ApJ, 846, 86

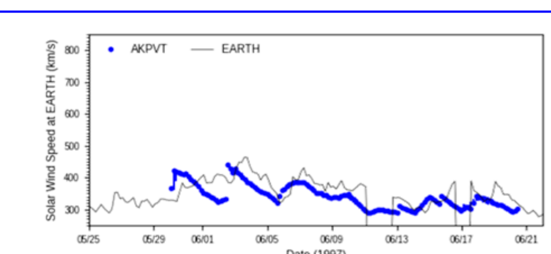
Daily images with solar wind speed measurements



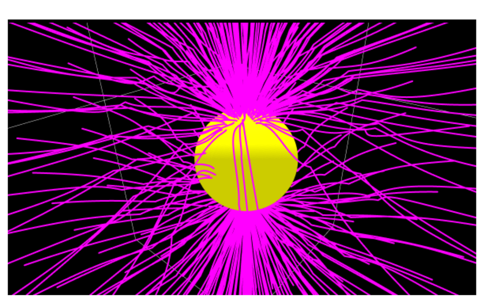
Cube of solar wind outflow velocity synoptics maps



Coronal magnetic field



WSA solar wind speed predictions vs measurements at 1 AU



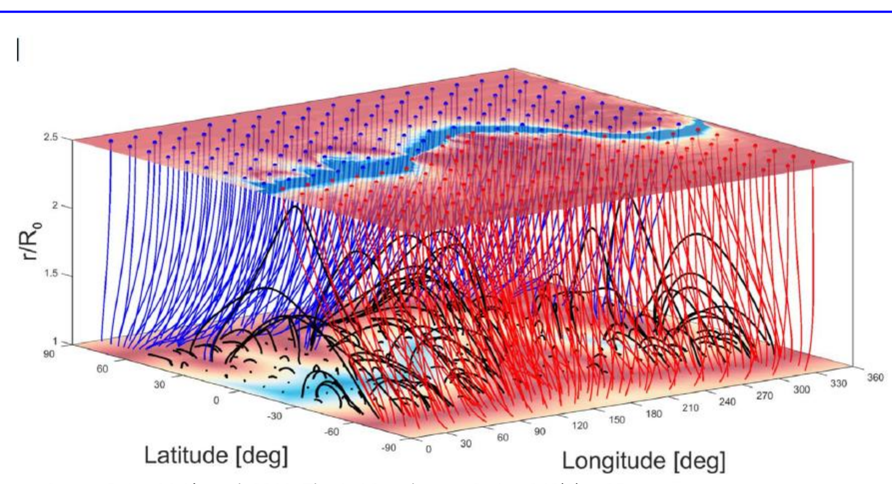
Open field lines extrapolated by WSA

The Wang-Sheeley-Arge (WSA) model (Wang & Sheeley 1992; Arge & Pizzo 2000; Arge+ 2003) is an empirical and physical-based model capable of predicting the solar wind speed and the interplanetary magnetic field (IMF) at 1 AU starting from the measured photospheric magnetic field by combining the magnetostatic Potential Field Source Surface (PFSS) and the Schatten Current Sheet (SCS). WSA derives twelve possible **configurations of the coronal magnetic field** based on twelve photospheric synchronic maps, that we refer to as *realizations*. The predicted solar wind speed and the IMF at 1AU is compared to the values measured in situ and the best realization is selected.

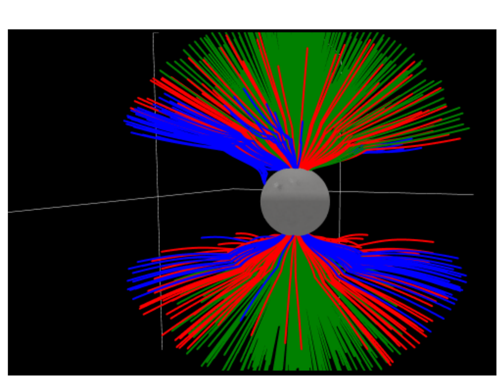
WSA provides the magnetic field configuration by tracking the open field lines back to their foot-point in the photosphere. Each field line is given as a sequence of points in space, together with the distance to the nearest coronal hole boundary of its foot point and its expansion factor.

Combining measured speed and derived magnetic field

Each point of the open magnetic field lines in the configuration derived by WSA is associated to a value of outflow velocity, based on its position (latitude, longitude, and solar radius).

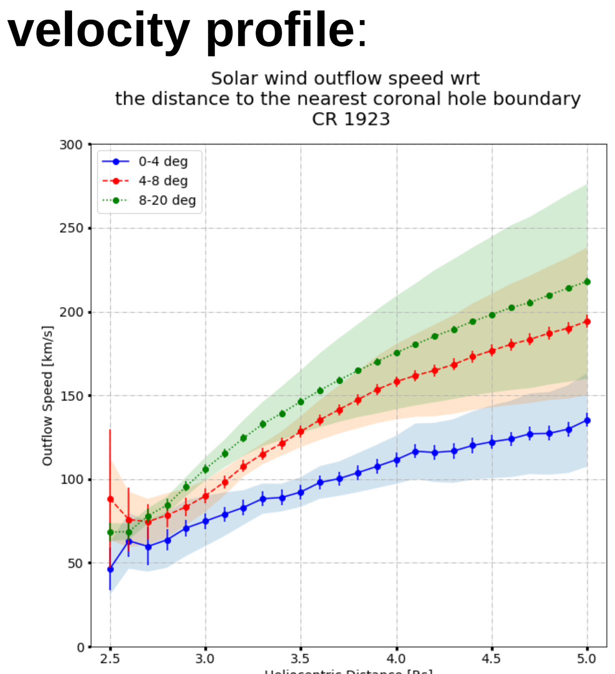


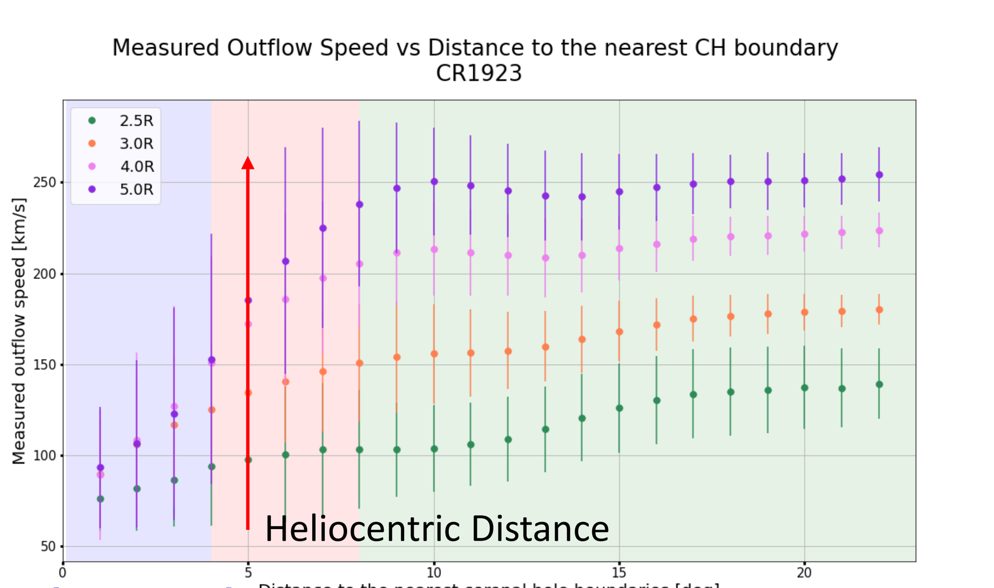
Source:Reiss, M.A', et al, 2019. *The ApJ Supplement Series*, *240*(2), p.35.



Open field lines are grouped based on the distance of their foot-point to the nearest coronal hole boundary

Example of derived **velocity profile**:





Lines with foot-point close to the boundary

Lines with foot-point deep inside the coronal hole

Results

This work aims at **enhancing the capabilities of the solar wind empirical models** by using measurements of the outflow speed referred to the acceleration region. This approach can be used to **analyze the relationship between the velocity and the characteristics of the magnetic lines** (e.g., expansion factor; proximity to coronal hole boundaries, active regions, and other structures; and magnetic topology), leading to new and improved, radially dependent, empirical relationships between the extrapolated global magnetic field and the solar wind velocity. The outflow speed profiles derived with this method are consistent with theory, demonstrating the usefulness of the technique: magnetic field lines rooted deep inside the coronal hole are associated with a faster speed, while those with foot-point close to the hole boundary are associated to slow solar wind.