Photospheric flows measured with the Coherent Structure Tracking (CST)

Thierry Roudier[1], Martine Chane-Yook[2], François Rincon[1], Michel Rieutord[1], Jean-Marie Malherbe[3]

(1) IRAP/CNRS/Observatoire Midi-Pyrénées, (2) IAS/CNRS/Université Paris-Saclay/OSUPS, (3) Observatoire de Paris

Principe of the CST

- Assume that granules are objects advected by an underlying flow which we wish to measure.
- The lifetime of a coherent object (granule) is defined between its appearance and disappearance.
- if granule splits : the structure issued from two or more merging granules is considered as a new granule.
- if granules merge : the lives of merging granules are stopped and the life of the new granule issued from merging starts.

WE CAN FOLLOW COHERENT STRUCTURES BETWEEN THEIR BIRTH AND DEATH

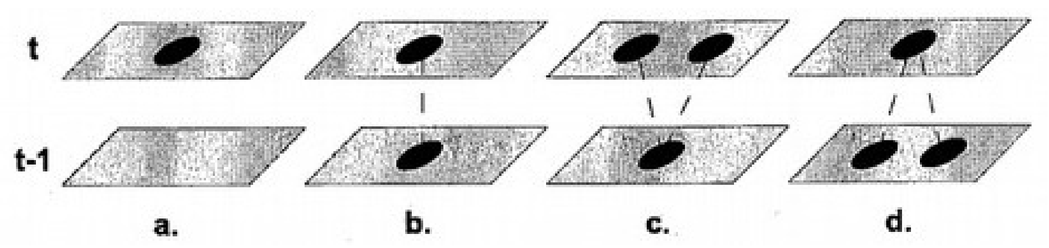

Figure 1:CST principe.

During their lifetime, granules can split or merge into multiple objects. Disappearence or appearance between two successive frames must be taken into account. Then, the life of coherent objects (i.e granules) is defined between its appearance and disappearance if the granule does not split or merge. When the granule splits (Fig. 1.c), the life of granule is stopped and its children are considered as new granules. In the same way, when granules merge (Fig. 1.d), the lives of the granules that merge are stopped and the new granule issued from the merging is considered as a new granule. Thus, we can follow a coherent structure between their birth and death.

Full Sun HMI/SDO data

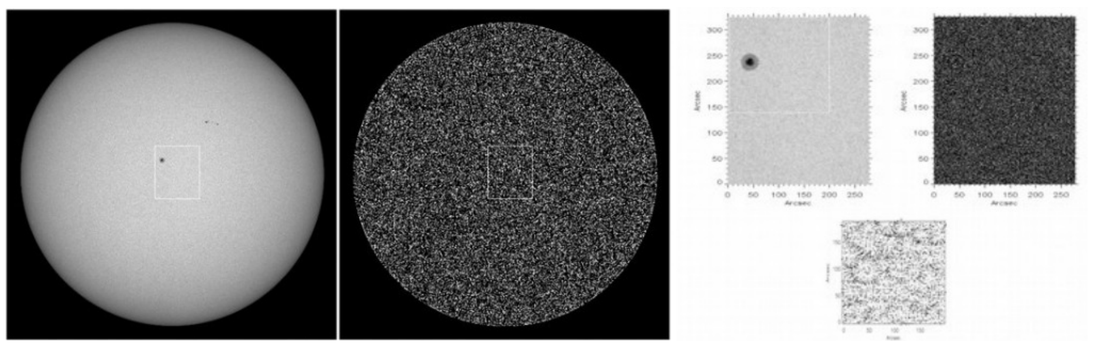

Figure 2:**On left:** Full Sun HMI/SDO white-light on August 30, 2010 (*left*) and the segmented map, in which about 500000 granules are detected (*right*). **On right:** Spatial (2.5 Mm) and temporal (30 mn) window.

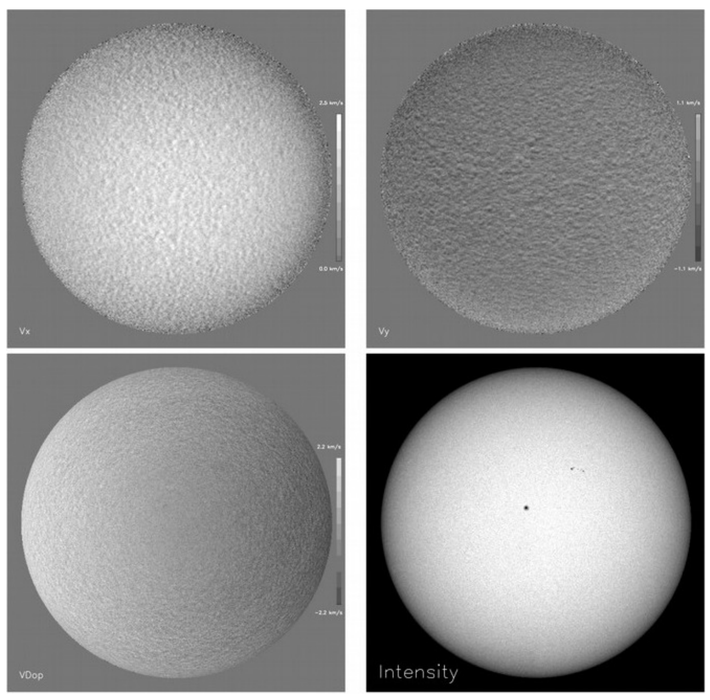

Figure 3:v_x, v_y, v_{Dop} velocity maps for the three-hour sequence on August 30, 2010, and the intensity at the beginning of the sequence.

Acknowledgments

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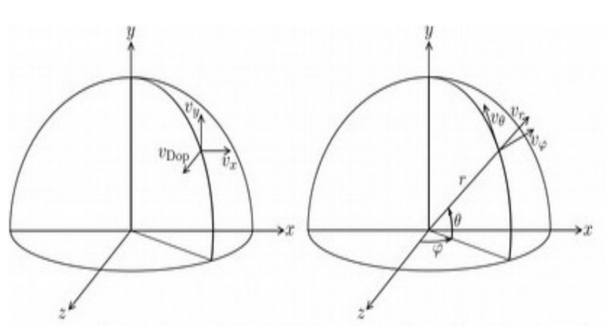
Full Sun HMI/SDO data



$$
\begin{aligned}
v_r(\theta,\varphi) &= \cos\theta * \sin\varphi * v_x \\
&\quad + (\sin\theta * \cos B_0 - \cos\theta * \cos\varphi * \sin B_0) * v_y \\
&\quad + (\cos\theta * \cos\varphi * \cos B_0 + \sin\theta * \sin B_0) * v_{\mathrm{Dop}} \\
v_\theta(\theta,\varphi) &= -\sin\theta * \sin\varphi * v_x \\
&\quad + (\sin\theta * \cos\varphi * \sin B_0 + \cos\theta * \cos B_0) * v_y \\
&\quad + (\cos\theta * \sin B_0 - \sin\theta * \cos\varphi * \cos B_0) * v_{\mathrm{Dop}} \\
v_\varphi(\theta,\varphi) &= \cos\varphi * v_x \\
&\quad + \sin\varphi * \sin B_0 * v_y \\
&\quad - \sin\varphi * \cos B_0 * v_{\mathrm{Dop}}.
\end{aligned}
$$

Figure 4:Coordinate systems used: velocity components in the sky plane V_x and V_y and the line of sight velocity V_{Dop} (*left*); velocity components on the solar surface V_r, V_φ, V_θ (*right*); θ: latitude, φ: longitude, B_0: angle.

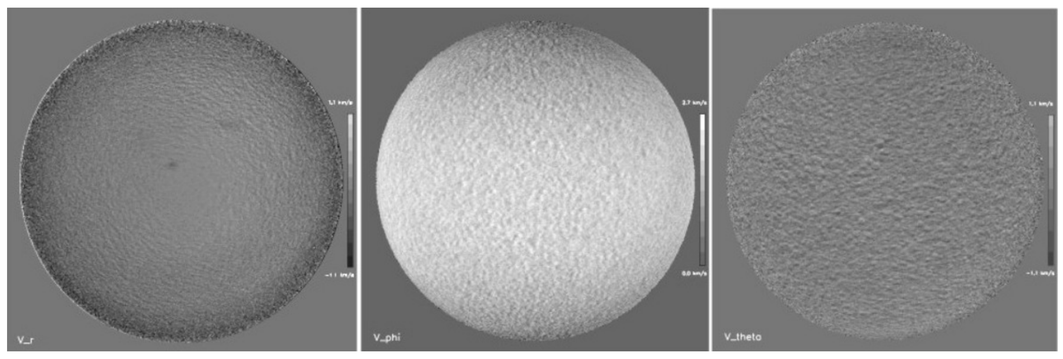


Figure 5:$V_r(\theta,\varphi)$, $V_\varphi(\theta,\varphi)$, $V_\theta(\theta,\varphi)$ for the three-hour sequence on August 30, 2010.

Results

CST results (movies), solar rotation, filament destabilization solar Coronna, dynamic of the photosphere.

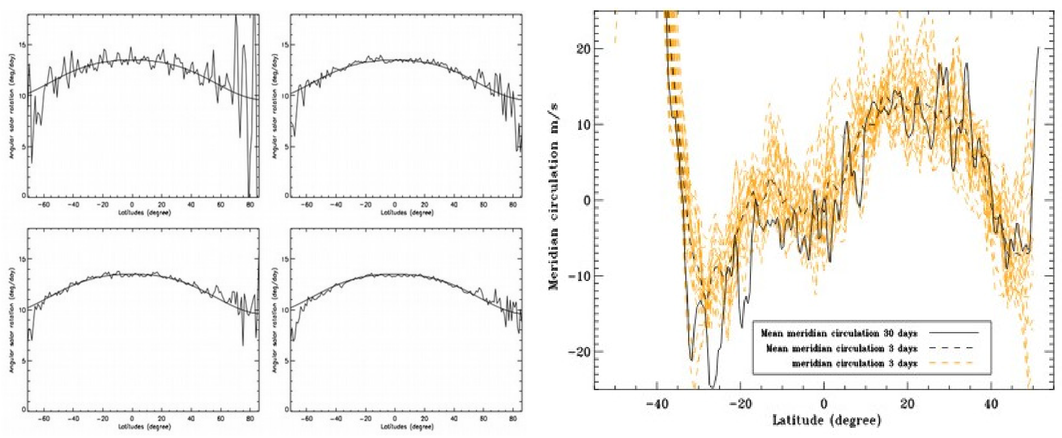


Figure 6:**On left:** Solar differential rotation by integrating 3h on August 30, 2010, computed for the four different angles : 2° (*top left*), 10° (*top right*), 20° (*bottom left*), 40° (*bottom right*) either side of the central meridian.**On right:** Meridional circulation measured with a moving temporal window of 3 days during the 30-day sequence (orange dashed line), meridional circulation issued from the temporal averaging of 30 days (solid line) and the average of all the 3-day averages (dashed lines).

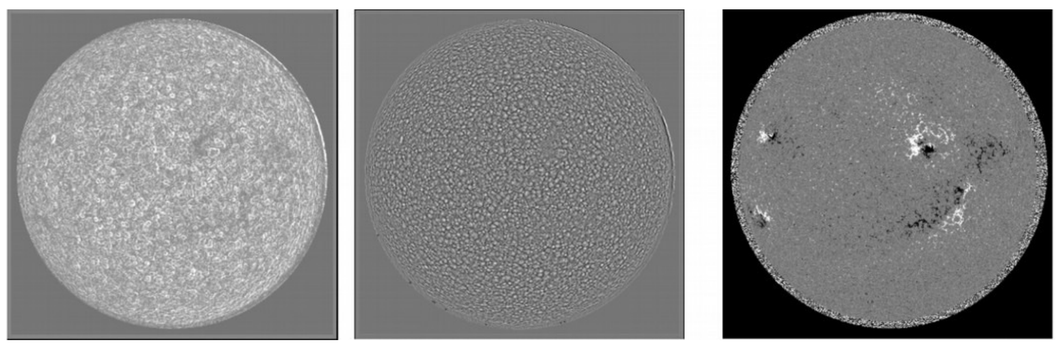


Figure 7:Module of (V_φ,V_θ) (*left*) and divergence map (*middle*) over a 24h time average. Longitudinal magnetic field (*right*).

Some references

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[3] Th. Roudier, M. Rieutord, V. Prat, J. M. Malherbe, N. Renon, Z. Frank, M. Švanda, T. Berger, R. Burston, and L. Gizon.
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Contact: thierry.roudier@irap.omp.eu CST codes available at: https://idoc.ias.u-psud.fr/MEDOC/CST codes