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G. Alecian, K. Belkacem, R. Samadi and D. Valls-Gabaud (eds)

PHOTOSPHERIC MOTIONS FROM AN OBSERVATIONAL POINT OF VIEW: HINODE AND SDO SATELLITE OBSERVATIONS

T. Roudier[1]

Abstract. Thanks to the Solar Optical Telescope onboard HINODE, we mainly aim at the understanding of temporal evolution and spatial characterization of solar granular and supergranular features and their relation with magnetic field. We study the photospheric motions and the network magnetic field interactions using the Tree of Fragmenting Granules (TFGs). The mutual interactions of the TFGs tend to expulse corks outside of them on 3h-4h and concentrate the corks on supergranular scale in approximatively 6h-8h to form the magnetic network. Then, the long living families contribute to form the magnetic network. The measurement of the horizontal velocities by the proper motion of granules over the full Sun with SDO data, allow us to determine, for the first time, the solar differential rotation directly at the central meridian. During the starting phase of the solar cycle 24, the solar differential rotation seems to show some modification which must be confirmed.

Keywords: Sun granulation, Sun photosphere, Sun rotation

1 Introduction

Understanding the distribution and diffusion of magnetic flux at the solar surface is of primary importance to describe many aspects of solar magnetism and activity, and notably requires to uncover the physical nature of flows at various scales which contribute to the transport of magnetic elements. The movements of the solar plasma generate magnetic field at different depths in the convection zone. The determination of these convective motions below the surface is a challenge which can be done using helioseismology but only in the first Megameters. However, today we can access to the solar surface motions over the entire solar disk.

Answering these questions requires high-resolution observations of the solar surface dynamics on a large field of view and for several consecutive hours. We present new observations from the HINODE and SDO satellites which fulfill some of these requirements.

2 Supergranulation and TFGs evolution from HINODE observation

The solar surface is now described as being structured in several sizes of "convective" scale: granulation, mesogranulation and supergranulation. From these three types of observed scale, only the physical nature of the solar granulation is really determined today. Hence, from many points of view, supergranulation is an essential element of the surface or atmospheric magnetic activity of the Sun. Its physical nature is still in debate and new measurements are required in order to progress in the understanding of its physical origin.

3D analysis (x, y, t) of the granular intensity field demonstrates that a significant fraction of the granules in the photosphere are organized in the form of Tree of Fragmenting Granules (TFGs, Roudier et al. 2003). A TFG consists of a family of repeatedly splitting granules, originating from a single granule (see Fig. 1).

The typical size of mature TFGs indicate that they trace some mesoscale rising plumes. In the old debate on the specificity of mesogranulation as a genuine scale of sub-photospheric convection rather then a mere extension of granular flow, TFGs point towards the genuine scale. Following the evolution of TFGs on two days showed their distribution among a supergranule which basically advects them. The use of floating corks demonstrates

[1] Institut de Recherche en Astrophysique et Planétologie, Université de Toulouse, CNRS, 14 avenue Edouard Belin, 31400 Toulouse, France

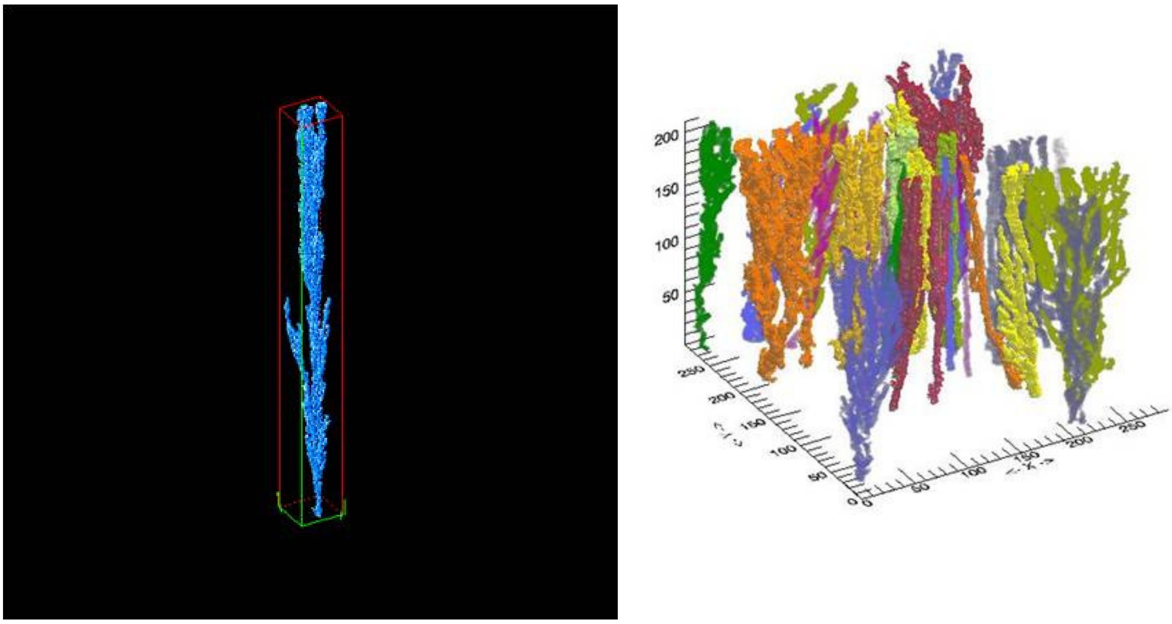

Fig. 1. Left: 3D (x, y, t) representation of a TFG with a lifetime of 8h10 which influenced a total area of $15'' \times 17''$. **Right:** Example of the 3D (x, y, t) evolution of different families in the same field.

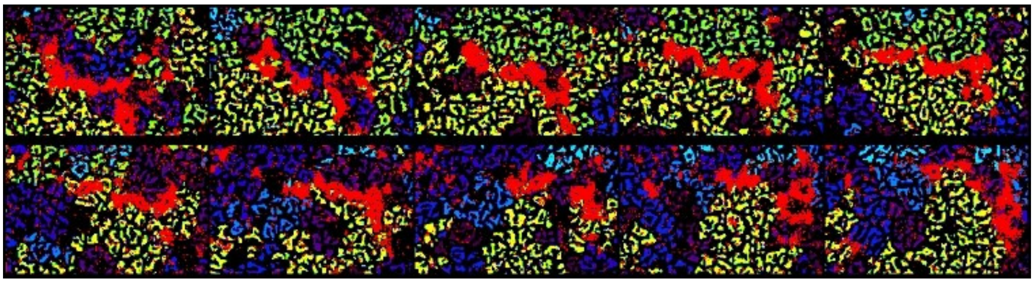

Fig. 2. Longitudinal magnetic field evolution, over ten hours, at the edge of a TFG (yellow). Time step between frame is 1 hour an the starting frame is on top left.

that final state of passively advected quantities like a magnetic field is a patchy distribution on the boundaries of a supergranule. This is confirmed by the observed evolution of the longitudinal magnetic field which is always located in the boarder of the TFGs (Fig. 2).

This is in agreement with the possibility that supergranulation is an emergent length scale building up as small magnetic element are displaced by TFGs flow, occasionally colliding and aggregating to form larger magnetic clusters with granulation which, can seed the supergranular downflow structure.

The temporal evolution of the magnetic elements, corks and TFGs are available at: `http://www.lesia.obspm.fr/perso/jean-marie-malherbe/papers/Hinode2008/`

3 Horizontal velocities over the Sun surface

For the first time, the motion of granules (solar plasma) has been followed over the full Sun surface, using SDO white light data. Horizontal velocity fields are derived from image correlation tracking using a new developped version of the Coherent Structure tracking (CST) algorithm (Rieutord et al. 2007).The spatial and temporal resolutions of the horizontal velocity map are respectively 2.5 Mm and 30 min (Figs. 3 and 4).

The measurement of the horizontal velocities over 24h at the central meridian, allowed us, for the first time,

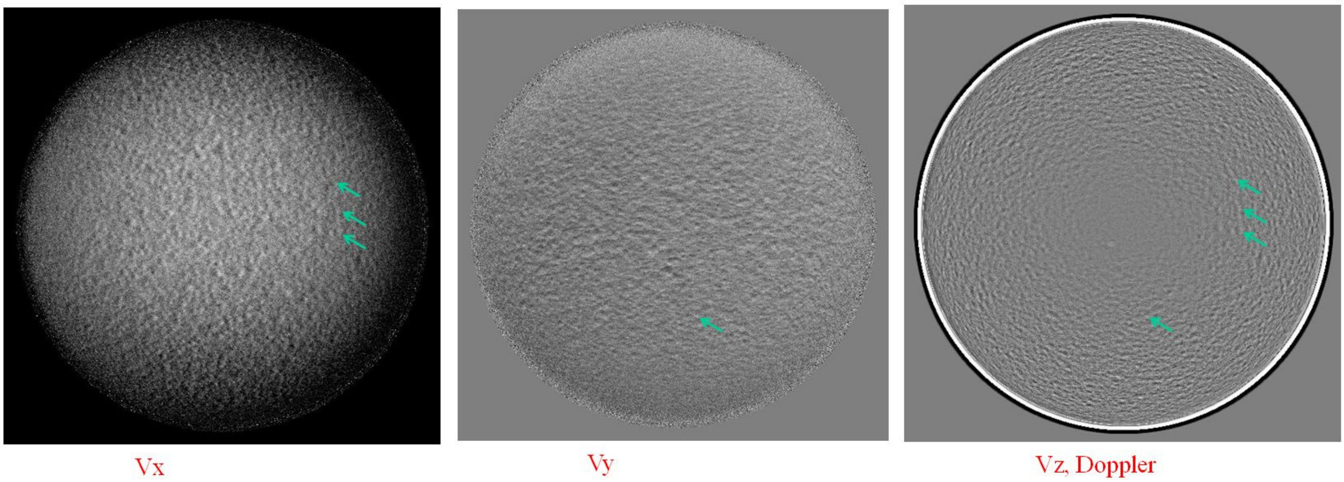

Fig. 3. Left: Full Sun Vx and (**Center**) Vy component from 2-hour sequence, spatial resolution = 2.5 Mm. Green arrows indicate the location of supergranule which are also visible (**Right**) on the Doppler map (2-hour sequence) where solar rotation has been removed.

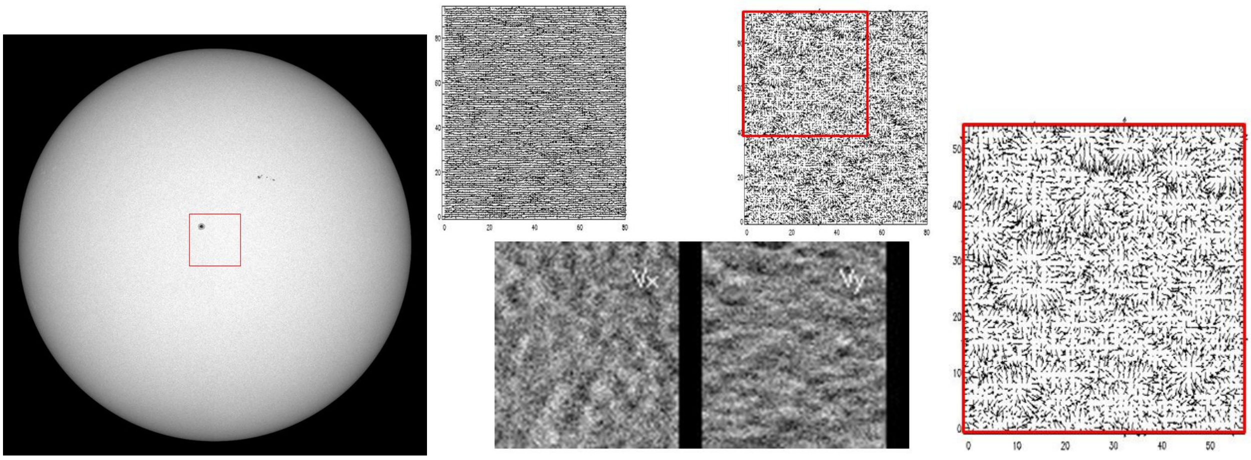

Fig. 4. Left: White light SDO observation on August 31, 2010. **Center:** Horizontal velocities (1-h sequence) details around sunspot with and without solar rotation (top left) and Vx and Vy component (bottom left), **Right:** Enlargment of flow fields around sunspot where divergent structures and also the sunspot moat are clearly visible. The field of view is $3.3' \times 3.3'$ and the spatial step is 2.5 Mm.

to determine the solar rotation from the granule displacement. Fig. 5 shows the differential rotation computed for four different dates close to the solar minimum. Our results are in agreement on April 10, 2010 with an error bar of 0.06 km/s, with the spectroscopic determination of the solar rotation (Howard et al. 1970) but the rotation seems faster with an equatorial velocity of 1.99 km/s for the other dates.

The dayly Wolf number are respectively 8, 14, 33, 26 and monthly 8, 16.1, 41.6. The solar differential rotation change in time particularly at high latitudes, but we need extensive analysis to confirm that variations. Today 1h20min are necessary to treat 30 min of observation. Improvements of the code are in progress. When the computation duration will be reasonable, the CST code will be implemented in the German Data Center for SDO and also given to Joint Science Operations Center), and will be available to solar community.

4 Conclusions

Thanks to a long 48 hours time sequence obtained with the SOT onboard HINODE, we confirm the organization of flows at the surface of the quiet Sun in the form of Trees of Fragmenting Granules. We quantified the contri-

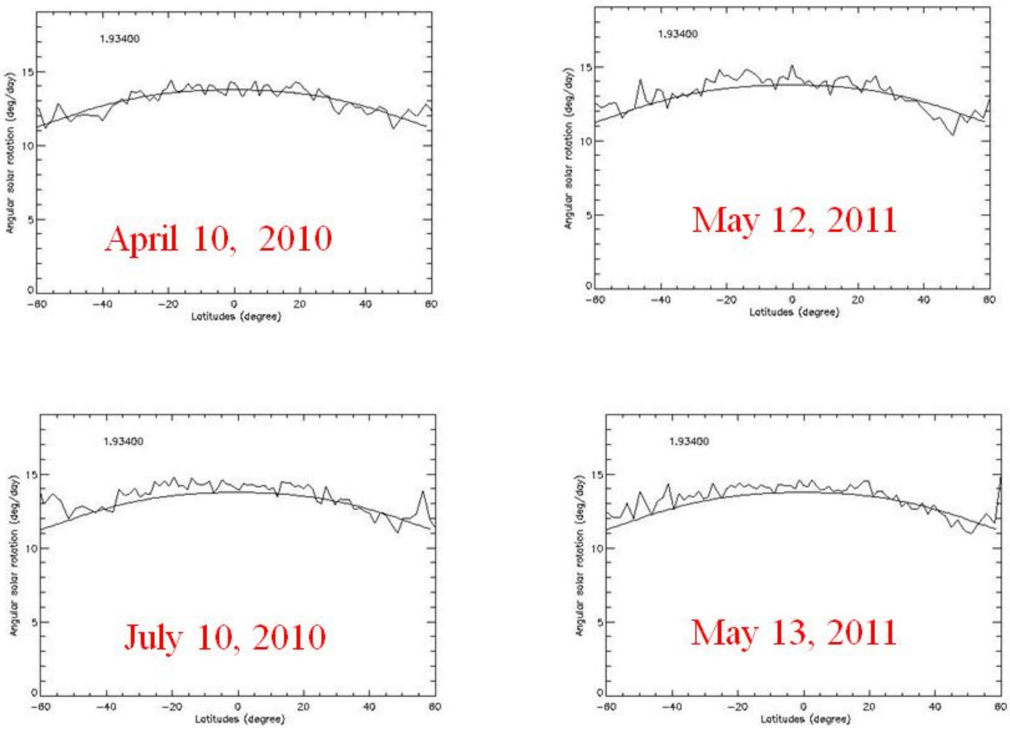

Fig. 5. Solar differential rotation from april 2010 to May 2011. The solid line is the rotation law determined by spectroscopic method (Howard et al. 1970) which is: $\omega = 13.76 - 1.74 \times [\sin(l))^2 - 2.19 \times (\sin(l)]^4$ (where l is the latitude and ω is the angular velocity in deg/day), giving an equatorial velocity of 1.93 km/s.

bution of these families to magnetic field diffusion in the quiet Sun and their role in building the photospheric network Roudier et al. (2003). The overlap between the distribution of floating corks and magnetic elements shows that magnetic fields get advected like a passive quantity before they end-up in a patchy distribution on supergranules boundaries. Presumably, these patches correspond to stable downwards flows that might be stabilized by the dynamical feedback provided by magnetic field concentrations.

For the first time, with the help of SDO white light data, the motions of granules (solar plasma) have been used to determine the projected velocities on the sky, over the full Sun surface. Many studies can be made at all spatial and temporal scales such as the determination of the photostpheric velocity field before, during and after an eruption (and CME). These subjects concern the solar weather research.

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