SOLAR STEREOSCOPY

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2. SOLAR STEREOSCOPY

ABSTRACT

We address the problem of the three dimensional viewing of actual solar images or of simulated magnetic fields.
It is achieved by a set of SOHO-EIT 304Å Hα images that we have made for SOHO 8. The solar chromosphere is viewed as a smooth convex surface located outside active regions and filaments. In a similar display of 193Å images the solar corona appears, by contrast, as an heterogeneous medium.

Animated stereo sequences of SOHO-EIT images are presented over two solar rotations from synoptic data. This allows not only structures in front of the solar disk to be seen but also the large coronal structures outside of the solar disk. These structures are seen in front as well as behind the solar disk.

The lenticular screen method needs no auxiliary viewing equipment. It is well suited for permanent display. By contrast the animated stereo display appears as a practical tool for investigating the 3D properties of actual or simulated solar coronas.

Keywords: stereoscopy, magnetic field lines.

1. INTRODUCTION

After our presentation of two practical undertakings in the field of solar stereoscopy during the SOHO 8 Workshop we comment here on this subject.

We remark that discussions of elaborate 3D computations of magnetic field structures are somehow camouflaged by the fact that their results are usually presented on a 2D screen. This inconvenience may be overcome by various means used independently or simultaneously: distinguishing close magnetic lines is made easier by color-coding them; drawing XYZ axes helps viewing perspective; complex structures are better understood when viewed in an animated sequence from continuously varying directions. We discuss here our presentation of two other methods.

2.1 Physical hypotheses

We consider here the remote sensing of the solar atmosphere and neglect in situ probing. Neatly defined terrestrial features such as rivers, roads or mountains, and some well defined opaque clouds such as cumulus clouds, have been recorded by extensive stereographic mapping of the correctly illuminated. Earth’s surface from aircraft or satellites. By contrast it is somehow difficult to match homologous points in both views of a stereo pair of more transparent clouds such as altostratus clouds. In the further case of an even more diffuse medium of a snow storm some studies of the turbulent and luminous nature of the flow velocities of snow flake have been performed at night by geometrical triangulation from three cameras synchronized by flashes.

Similarly, solar features are more or less well suited for stereographic mapping depending on their opacities. The opacities are determined by the physical conditions within the structures and the wavelength of investigation. When considering that the signal observed in each pixel of an image is an integral involving the local values of emissivity and absorption along the line of sight one may even argue that studies of the three dimensional nature of solar structures belong more to tomography than to stereoscopy. In our opinion the results of two undertakings that we displayed during the SOHO 8 workshop demonstrate that stereoscopy is a good first approximation of tomography.

2.2 Geometrical hypotheses: rotational solar stereoscopy

Once the principle of studying the three dimensional nature of solar structures by stereoscopic methods is accepted it remains to implement it, i.e. to obtain stereo pairs of the Sun from as many directions as possible with a difference in viewing angle of the order of 2°. The difference is far too small for the case of two terrestrial observatories even if they are far apart in latitude or longitude. Simultaneously viewing the Sun with two identical instruments from a larger angle in the east west direction was accomplished from SOHO and from the Earth on October 18, 1997 during a rocket calibration.

flight of the EIT telescope. The observed perspective shift actually observed is still too small. Larger viewing angles in the east-west direction from Earth and from the first STEREO missions were obtained in the field of radio astronomy. As a result, the directional radio emissivity of solar structures has been precisely determined. Larger viewing angles in the north-south direction from Earth and from the ULYSSES spacecraft could not be obtained because of the lack of optical instruments on the spacecraft. The planned STEREO mission should provide, in the near future, observations widely spaced in the east-west direction.

Meanwhile, rotational solar stereoscopy is a substitute for quasi instantaneous observations from two distant points of view. Taking into account the apparent rotation period of the Sun, of the order of 25 days, a simple reasoning or an even simpler trial method indicates that for a classical presentation, i.e., north up, presenting to the right eye a solar image taken at time T and to the left eye an image at time T+ΔT allows a view of the solar atmosphere with its correct positive convexity.

2.3 application
The apparent convexity increases with the time delay ΔT. At the same time the solar structures evolve and the percentage of homologous points between the left and right images decreases. A good compromise between these two effects, i.e., increasing strength and decreasing quality of relief, is found for 3 hours < ΔT < 9 hours.

Implementing rotational stereoscopy from ground based observations is made difficult by three phenomena: interruptions by night or by atmospheric conditions, differential refraction, and variations of the position of the solar rotation axis with respect to the axes of an azimuthal or equatorial mounting. Using satellites the first two phenomena are eliminated, and additionally on board some three axis stabilized spacecrafts, such as SOHO, stellar sensors allow a continuous adjustment of one axis of the field of view in a direction parallel to the projected solar axis. In this way the two images of a pair are aligned without any processing.

Sections 3 and 4 describe two applications of rotational stereoscopy beyond the classical presentations of a still stereo pair.

3. STEREO VIEWING WHITOUT SPECTACLES

3.1 choice of a method
Standard stereoscopic techniques usually involve some kind of spectacles in order to present different views to the left and right eyes. Doing whitout spectacles is made possible by at least three methods.

Crossed viewing is obtained when locating the right view to the left of the observer and vice versa. This method is well suited for intensive data screening on a computer screen despite two drawbacks. Firstly, it requires some training. Secondly, in the field of solar rotational stereoscopy it is often required to further examine a structure in order to know if it actually appears in both views of the pair or if it is a ghost feature present in only a single view. Setting the question by alternatively closing the right and left eye is easily accomplished when both images are presented close together and left/right separated with ad-hoc spectacles i.e. when viewing either anaglyphs with hue and red spectacles or slides projected on a metallic screen with polarizing spectacles. In the case of crossed viewing the fact that the two images are widely separated, prevents an easy discrimination between real and ghost features.

The implementation of holographic techniques in the fields of solar observations or solar simulations would be desirable because holograms present two advantages: firstly, no spectacles are required; secondly, a single display furnishes several different viewing angles.

3.2 simultaneous presentation of several images
The lenticular screen method has likewise the same properties. We presented during the SOHO 8 workshop a set of 20 SOHO EIT 30'A HeII images 56mn apart. Each image is divided into 700 vertical stripes. Behind each of the 700 cylindrical lenses of a lenticular grating are located the 20 corresponding stripes in order that the left and right eyes of an observer, located at a suitable distance, receive images separated by a few hours of time. In this way a stereoscopic view is obtained without spectacles and, additionally, stereo pairs at different times are observed by moving sideways. The solar chromosphere is viewed as a smooth convex surface outside the location of active regions or filaments. The global shape perceived is not truly spherical as the surface of the Sun does not rotate rigidly.

We applied the same method to a similar set of solar corona images in the Fe XII line at 195Å. The overall convexity of the solar corona is not perceived as well as for the solar chromosphere because the coronal structures appear to float in space rather than to be distributed over a smooth surface.

4. ANIMATED SOLAR STEREOSCOPIC TIME SEQUENCES

4.1 generalities
When merging the two views of a static stereoscopic pair corresponding to moments separated by a few hours of time it appears that some real structures are seen in relief and some appear as ghost features. In addition to the blinking method used to distinguish between them a more confortable discriminating tool is provided by playing back and forth an animated sequence of stereo pairs. At the SOHO 8 workshop we displayed an implementation of this technique currently in use in the field of molecular chemistry.

Left and right views are alternatively displayed on a computer screen. The left and right glasses of a pair of liquid crystal spectacles are also alternatively opaque or transparent. If the two devices are well synchronized at a sufficiently high rate each eye of the observer perceive
an animated left or right sequence. This provides in a short time sequence several stereoscopic views of a molecular model from different viewing angles, and from varying distances, with the following result: whereas it is difficult to perceive at first sight from a static pair the three dimensional structure of some complex molecules it is on the other hand possible to obtain a clearer understanding of this structure, from the very same static display, after some instants of hand controlled animated viewing.

4.2 Implementation

In our case we have only one degree of freedom, a rotation back and forth from east to west.

From a set of 363 images 7 minutes apart we made some experiments with two parameters, respectively the base or the time interval between the two views of each pair and the cadence, related to the time interval between two consecutive pairs. During animations with a long base at high cadence ghost images of single events appear twice and are more easily discerned than from direct animations.

Matching the cadence to the base in order to obtain the best relief is accomplished when the time interval between two consecutive pairs is of the same order as the time interval between the two views of each pair.

From data of the EIT synoptic program, of four sets of four images taken at four different chromospheric and coronal wavelengths, during the SOHO 8 workshop we presented several animations covering almost two solar rotations.

4.3 Results

We noted that it is possible during animations to observe an unquestionable convexity for a shorter base than during static display, with the benefit of a better relief due to a higher percentage of homologous points. In other words, the stereoscopic sensitivity is higher for animations than for static display.

A further difference between static and animated stereoscopy appears when we take into account the fact that the solar observations in the EUV display the corona simultaneously outside of the solar disk and in front of the solar disk, whereas the field of view of white light images from coronagraphs is obstructed by an occulting disk. We note that from static pairs a clear perception of relief is obtained only for structures located between the solar disk and the observer. The situation outside of the solar disk is somehow confusing. By contrast during stereo animations from the very same data some coronal structures appear unambiguously in a solar longitude range spanning more than 180°.

5. Discussion

5.1 Numerical Investigations

Whatever stereoscopic viewing method is used the perceived solar convexity is not truly spherical. This arises from two different phenomena, on the one hand the solar differential rotation and on the other the non zero angle between the solar axis of rotation and the normal to the ecliptic. Taking into account the latter effect we measured the apparent rotational velocities of solar structures. This involves cross-correlation techniques from images converted to heliographic coordinates. The precision depends upon the shape, stability and lifetime of structures. Our first statistics indicate significant departures from an average solar differential rotation curve as a function of solar latitude. There is a systematic trend for positive, high speed departures from the average. This systematic trend is attributed to a geometrical effect of the altitude of coronal structures above the photosphere. Observations from two points widely spaced in the heliosphere would help to better discriminate such geometrical effects from true proper motions.

5.2 Choice of a Stereoscopic Method

The implementation of the method described in section 3.2 requires some special equipment such as a high precision computer printer and a lenticular screen. As no viewing equipment is required, this method is well suited for permanent displays of observations and models and for educational purposes.

The implementation of the method described in section 4.2 is relatively easy and should be applied to all data from the synoptic program of EIT. According to our experiments on a limited set of very high cadence images we suggest an increase in the cadence from four points per day to six or eight points.

5.3 Extrapolations

The STEREO mission was proposed in order to investigate in the near future the three-dimensional nature of the heliosphere. The shortcomings of rotational stereoscopy described in section 2.2 will then be overcome, neglecting spurious time delays due to the finite speed of light. With respect to the problems mentioned in section 2.1 we estimate, based on our animated presentation, that EUV observations at an hourly cadence will allow a localization in space of the near Sun structures in the solar corona.

6. Acknowledgements

The implementation of the lenticular screen method is made by Espace 3D, Patrick Garret, 255, rue du Fbg Saint Martin, 75010 Paris, 33 1 42 99 11 80.

We acknowledge a loan of equipment from Silicon Graphics and from Pixel Tech for animated stereo.

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