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3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE:

3D Reconstruction of stereoscopic images from EUVI/SECCHI

PARTICIPANTS:

Markus J. Aschwanden (1)
Jim Lemen (1)
Jean-Pierre Wuelser (1)
David Alexander (2)

CONSORTIUM INSTITUTIONS:

(1) Lockheed Martin, Solar & Astrophysics Laboratory, Palo Alto
(2) Rice University, Houston

GOAL FOR THE FINAL PRODUCT:

We plan to develop a number of 3D reconstruction and visualization tools, using input observations from SECCHI EUVI imager on both spacecraft STEREO-A and B, possibly including data of the same wavelengths from a third vantage point obtained by SOHO/EIT and TRACE. The software modules will be made available to the general user on the SSW (Solar Software/IDL) platform and examples and tutorials will be provided on webpages. The 3D reconstruction algorithms will be tailored to different phenomena, such as

(1) 1D-linear structures (loops, filaments, fluxropes
(2) 2D-surface structures (CME fronts)
(3) 3D-volume structures (complex CME structures)

The 3D reconstruction can be

(a) time-independent (from a single pair of stereo images)
(b) time-dependent (using constraints from a movie of stereo images)

Further software will be developed for different rendering techniques of 3D products (light-and-shadow representation, rotating 3D cubes, etc.)
The goal is to give the user some elementary or first-level software to analyze EUVI data on a basic level. We will provide simulations and analysis results on the LMSAL/EUVI webpages.

PROGRESS TO DATE

Previous work is documented on the LMSAL/EUVI webpages:
http://secchi.lmsal.com/Science/
STEREO Data simulations:
HTML, FITS files, 171 A and 195 A movies of

-active regions containing several 100 hydrostatic loops
with different heating rates and background noise
-Dynamic model of Bastille-day flare (200 loops)
-Dynamic model of postflare arcade rotating around Sun
-Dynamic model of an erupting arcade rotating around Sun
-Dynamic model of CME launch

STEREO Software Developments:
IDL/STEREO package for coordinate transformations
and loop geometry tools
and stereoscopy tools for single loops

HTML and POWERPOINT Presentations:
11 presentations from
2000: AGU San Francisco,
STEREO workshop, Easton Maryland
2001: 2nd SECCHI Mtg Abington, UK
2002: SECCHI Consortium Mtg Stanford,
1st STEREO WOrkshop, Paris, France
2003: STEREO workshop, UC California, Berkeley

Description of existing software:
The coordinate transformations provide conversions from image coordinates into heliographic coordinates and loop plane coordinates. This software has been extensively tested before, for image overlays from different times (compensating for solar rotation) and for stereoscopy work with other datasets (VLA, OVRO).

The 3D reconstruction software is so far limited to single loops with a 1D parameterization. The user can outline a loop in STEREO image 1 and either find the expected projection in STEREO image 2 based on some geometric model (e.g., circular) or fit the two projections with a geometric model to obtain the required geometric parameters (e.g. inclination angle of loop plane).

FUTURE PLAN OF WORK

Two STEREO images (of optically-thin EUV or soft X-ray emission) provide only partial constraints to reconstruct the 3-D distribution of a plasma. The problem is underconstrained, except for linear (1D) features. Therefore, some additional a priori constraints can be introduced to provide a 3-D solution. The pixon method minimizes, similar to maximum entropy methods, the number of voxons (non-equidistant voxels), the 3D analogy to 2D pixons (non-equidistant pixel areas). However, even the pixon solution is not unique and depends on the choice of elementary geometric structures (e.g., the NRL group used semi-shell structures in one demonstration).

We are planning to explore other constraints that lead to 3D solutions with the goal of optimizing (1) problem-oriented constraints and (2) computational speed. For instance we plan to implement a method where a structure is represented by a

finite number of 3D gaussian distributions, similar to the Multi-resolution Clean method, which worked fine for stereoscopy of free-free emission of full-disk maps at microwave frequencies (Aschwanden & Bastian 1994, ApJ). We envision a strategy of reconstructing first line-of-sight planes with a minimum number of structures, which can be used to bootstrap adjacent line-of-sight planes with more complex nested structures. Furthermore, time series can be used to bootstrap the 3D solutions of times with complex structures by using the 3D solutions of earlier times with simpler structures as initial-guess. First steps and tests in the development of such numeric codes are underway at LMSAL.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE
Differential Emission Measure (DEM) Tool for EUVI

PARTICIPANT(S)
John Cook and Jeff Newmark

CONSORTIUM INSTITUTION(S)
Naval Research Lab

GOAL FOR THE FINAL PRODUCT
We have developed an existing code for EIT on SOHO which produces a DEM map of the EIT field-of-view using images from each of the four EIT channels, exposed within 20 min of each other. The DEM map is an individual DEM curve for every pixel, each covering a temperature range from log T = 4.5 to 6.5. The DEM map allows the calculation of a synthetic image in any individual line or wavelength passband (to mimic a real or model instrument) in our temperature range where the emissions arise from allowed lines (or forbidden lines emitting in a density regime where they still behave as allowed lines) in an optically thin plasma.

Intensity images from the DEM map also directly allow the calculation of the full disk flux, which is the irradiance when adjusted for a distance from the Sun of 1 AU toward Earth. The tool includes this calculation. Long-term synoptic comparisons with available irradiance observations, such as the SEM 260-340 A irradiance, have increased our confidence in the accuracy of the DEM tool.

PROGRESS TO DATE
We have been using the EIT version of this tool with great success. This is a completed tool for EIT.

FUTURE PLAN OF WORK

When finally available we will incorporate the exact measured passbands of the individual EUVI channels and the instrumental absolute calibration into our DEM tool. We already examined idealized synthetic passbands in earlier studies for the EUVI channels, and there should be no problems in changing the passband - absolute calibration section of the program to a EUVI-specific version.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE

3D Reconstruction of White Light Coronagraph Images from Multiple Viewpoints

PARTICIPANT(S)

John Cook, Jeff Newmark, Paul Reiser, and Amos Yahil

CONSORTIUM INSTITUTION(S)

Naval Research Lab

GOAL FOR THE FINAL PRODUCT

We aim for a finished, tested computer code to perform true tomographic reconstruction of electron densities in an n^3 volume, using input observations from the SECCHI coronagraphs Cor 1, Cor 2, and HI on both STEREO spacecraft and possibly LASCO observations from SOHO. The reconstruction problem is inherently underdetermined from the limited available viewpoints, and we will study the limitations of the achievable reconstructions, and the quality of the reconstructions for changing spacecraft orbital positions as they separate in angle from Earth. The input data are 1024x1024 resolution coronagraph images, and our mission goal is to achieve 512^3 resolution reconstructions of a volume commensurate with the observed common field-of-view of the contributing coronagraphs.

PROGRESS TO DATE

We have presented on our work at the various SECCHI consortium meetings since Abingdon, and also at the Paris STEREO meeting and the most recent Solar Physics Division meeting (summer 2003). We are now in the second year of a three year NASA LWS TR&T proposal effort. I have taken material from our first year NASA progress report for this text. There is also useful material on our team web site.

Our reconstruction engine is the commercial PIXON code, now applied to three dimensions. Our working team includes Amos Yahil of PIXON LLC. For application to coronagraph observations, we have incorporated in the line-of-sight sampling function the full white light Thomson scattering physics, with polarization, the full geometry of the lines-of-sight integrations to the detector pixels, and the illuminating solar surface intensity with realistic center-to-limb variation, all in our computer code.

We began our serious 3D electron density reconstructions with simple geometrical structures, especially a Sun-pointing constant density half shell to mimic a CME. We progressed to numerical CME models, first the Jim Chen flux rope model, and then numerical MHD code models contributed by Zoran Mikic, Paulett Liewer, and S.-T. Wu. These models contain a more realistic range of electron density values, spanning many orders of magnitude, in the volume of interest. We concentrated our reconstructions this year on the Chen flux rope model. We have placed several past presentations of our work, including diagnostic figures from several of our reconstructions, on the NRL STEREO SECCHI web page, at stereo.nrl.navy.mil. Selecting the "3D R&V" (3D reconstruction and visualization) tab on the left side of the page, this work can be reached.

The twin STEREO spacecraft will obtain observations from just two viewpoints. We studied the improvement obtained by using an additional third viewpoint, which might be provided by an operational SOHO coronagraph. Just as a demonstration of the often doubted usefulness of tomographic reconstructions from a limited number of viewpoints, we also performed half shell and Chen flux rope reconstructions from two ecliptic plane viewpoints and a third, polar axis, viewpoint. We did this to demonstrate that the truer problem in obtaining genuinely useful reconstructions from real coronagraphs is not so much just the limited number of viewpoints, but more importantly, the confinement of the available viewpoints to the near-ecliptic plane. However, there is very definitely an improvement in reconstruction from even the additional ecliptic plane SOHO viewpoint.

After gaining this experience with reconstructions, we decided that we needed to improve the speed efficiency of the basic PIXON engine. Even with only 128^3 volume resolutions, a reasonable reconstruction was taking many days of computer time. After considering several possibilities, we decided to implement a new hierarchical scheme in the basic PIXON reconstruction engine. We start with a largest-sized "supervoxel" division of the volume, fit the part of the electron density distribution constant in individual supervoxels, and then proceed to smaller supervoxels, finally reaching the full resolution voxel size of the calculation. The full reconstruction is the sum of the hierarchical supervoxel solutions in the final iteration of the PIXON engine, reached when the chi-squared fit to the starting coronagraph observations reaches a pre-chosen value, usually the noise level of the observations.

While waiting for Amos Yahil to implement this new PIXON hierarchical algorithm, we at NRL have most recently started on applying PIXON reconstruction to the off-limb corona of SOHO EIT 195 A images, using rotational tomography. This is not meant to reconstruct the smaller scale, complex loop systems on the disk, but instead the larger scale high coronal structure out to 1.3 R. We have modified the intensity in the line-of-sight integral to depend on Ne^2 and the atomic physics coefficient appropriate for 195 A line radiation from collisions populating the upper level. We assign zero statistical weight to disk pixels in the EIT data, and only use the off-limb data in the reconstruction of the off-limb electron densities.

FUTURE PLAN OF WORK

We will complete the PIXON reconstruction engine improvements, and move on to our final goal of 512^3 - size reconstructions. We will benchmark our timing improvements, and determine realistic estimates of the time it will take to perform reconstructions with the SECCHI coronagraph observations from STEREO.

We will resume our numerical CME model reconstructions, and examine the problem of determining a useful quiet background for subtraction from the full range observations (for both synthetic and then for real data) to isolate the evolving CME in reconstructions. We will model synthetic data from the Heliospheric Imager coronagraphs on SECCHI and begin reconstructions with these non - Sun centered observations. We hope that the new SMEI data, with its implications for the HI data, will be helpful also.

We will continue with our reconstructions using SOHO data, both the EIT off-limb reconstructions we have already begun, and LASCO data studies. These studies use rotational tomography, where the rotating Sun substitutes for genuinely simultaneous multiple lines-of-sight. Of course, this can only reconstruct volumes which are not substantially evolving over the rotational period being reconstructed. We must carefully choose the features being studied, and this technique is not appropriate for CMEs. The goal is to gain experience with real data.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE:
Streamer Simulation

PARTICIPANT(S)
Angelos Vourlidas, Christoph Marque

CONSORTIUM INSTITUTION(S)
Naval Research Laboratory

GOAL FOR THE FINAL PRODUCT
An easy-to-use streamer simulator. The use will be able to locate a radial streamer (of a given width) anywhere on the solar surface and calculate its total and polarized brightness as would be recorded by an observer on the earth or on the STEREO S/C. We will also investigate the feasibility of adding multiple streamers.

PROGRESS TO DATE
The simulation is based on an old Fortran program, translated to IDL (by J. Wendt) and is currently working,

FUTURE PLAN OF WORK
Increase the execution speed.
Investigate the possibility of having multiple streamers.
Integrate the program with the rest of the SECCHI software.
Make it user-friendly

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE:
CME Mass & Energetics Toolbox

PARTICIPANT(S)
Angelos Vourlidas

CONSORTIUM INSTITUTION(S)
Naval Research Laboratory

GOAL FOR THE FINAL PRODUCT
Provide a collection of IDL routines and a user-friendly interface to allow the derivation of mass and energetics for one or many CME events. Some of the data products to be provide by this toolbox are: mass, kinetic and potential energy, estimates of magnetic energy, center-of-mass height and position angle.

PROGRESS TO DATE
Most of the routines are alreay in place and used in the analysis of LASCO data. There's no GUI to integrate these programs together.

FUTURE PLAN OF WORK
Define the GUI in conformance with the overall SECCHI GUI requirements.
Update the IDL routines to make use of the dual coronagraph data input.
Integrate the program with the rest of the SECCHI software.
Make it user-friendly

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE
Tie Point Tool

PARTICIPANT(S)
Eric De Jong, Paulett Liewer, Jeff Hall, Jean Lorre

CONSORTIUM INSTITUTION(S) JPL

Tool for manually creating tiepoints between features in a SECCHI stereo image pair and for solving for the 3D location in the heliographic coordinate system. Minimum platform-independent tool displays the two images, reads location of tiepoints placed manually with cursor, and creates an ascii tiepoint file. The tiepoint file is the input to the program xyzsun which computes the 3D location of the tie pointed feature.

PROGRESS TO DATE
Tool exists now running under the VICAR programming environment. Now creating a platform independent version.

FUTURE PLAN OF WORK
Will finish conversion to platform-independent code.

Also plan to provide 3D visualization capability (shuttered googles) which will require special hardware. This would allow visualization of the stereo pair and the 3D location of the tie-pointed feature.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE
SynLOS: Synthetic LOS Tool for SECCHI white light images

PARTICIPANT(S)
Paulett Liewer, Jeff Hall, Jean Lorre

CONSORTIUM INSTITUTION(S) JPL,NRL
Tool for creating synthetic SECCHI white light images from user-supplied 3D density data cube. Tool understands fov of SECCHI coronagraphs and heliospheric imagers (including CCD size) and creates the synthetic line-of-sight coronagraph image for the telescope using thomson scattering and ray tracing. Note that images are additive so resulting image can be added to background image. Design to be a simple tool for science planning.

Input: user-supplied density cube den(i,j,k) on a cubic grid
SC angle from Earth
Output: synthetic SECCHI image in fits format with proper SECCHI header.

PROGRESS TO DATE
Tool well developed, but not specialized to SECCHI yet. Will complete this year.

FUTURE PLAN OF WORK
Use tool with simple CME models, etc., to understand appearance of same feature from different angles and from different instruments, eg. COR2 on SCA and HI1 or SCB.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE
Finite Element Tomography code (FETOC)

PARTICIPANT
Bernd Inhester

CONSORTIUM INSTITUTION
Max-Planck-Institut f"ur Aeronomie, MPAE
(after 1st June: Max-Planck-Institut for Solar System Research, MPS)

GOAL FOR THE FINAL PRODUCT
This will be a conventional fully 3D tomography inversion code (not stacked 2D layers). As input any number of images larger than 1 is tolerated, image gaps and partial images are acceptable. The code will be capable of using additional information from a given coronal magnetic field model if available to achieve an improved resolution. The output will be an approximation of the 3D electron density or the local volume luminosity given as conformal P_1 Lagrangian elements on a quasi-irregular tetrahedral grid. The grid resolution depends on the computer resources with storage being more important than cpu time. Since the grid can in principle be chosen freely, we may add an adaptive grid refinement option.

PROGRESS TO DATE
The basics of the code is done. We can run tests with simulated data to check its performance. Regularization with or without magnetic field works in a test mode but still needs to be properly be built into the code. We have a F77 and a F95 version of the code. The former is faster but we think of doing the final version in F95 for clarity of the code. Documentation has been started but is not quite up to date with more recent changes in the code.

FUTURE PLAN OF WORK
The code is reasonably fast (returns 3D results with 0.05 R_sun resolution within seconds on an ordinary PC) once the grid is set up. The performance can still be improved because by now we do not yet use preconditioning of the CG iteration. Also the code has a high potential for being parallelized which has not yet been exploited.

The price we have to pay for the flexibility of the grid is that it takes much more time to set up the grid than doing the inversion. If the grid will not be changed, it can however be saved and used repeatedly on different input data. The storage may become a problem if high resolution is required: a 0.05 R_sun resolution grid needs ~ 60 MB right now and grows as (grid size)**3.5, roughly. This may be improved slightly if we carefully distinguish which data really needs to be stored and which can cheaply be recalculated when needed.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE
Stereoscopy of EUV loops

PARTICIPANT
Fabrice Portier-Fozzani 1) and Bernd Inhester

CONSORTIUM INSTITUTION
Max-Planck-Institut f"ur Aeronomie, MPAE
(after 1st June: Max-Planck-Institut for Solar System Research, MPS)
1) now at: University of Athens, Greece

GOAL FOR THE FINAL PRODUCT
We may be able to produce a tool which automatically produces 3D loop systems from two or more EUV loop images.

PROGRESS TO DATE
We have a program which rectifies a pair of images into epipolar geometry and a line-tying 3D reconstruction of loops once they are supplied as 2D curves. What is missing and is the most difficult step is extracting curves from the two images and matching them.
We have not worked intensively on this problem in the past but from what seems clear to us, magnetic field information also helps greatly to rule out unphysical loops which yet satisfy the optical data.

FUTURE PLAN OF WORK
Right now, we cannot make a promise how far we will get with this tool at the time of the launch. At any case, it will be very much interlinked with reconstruction tool for magnetic fields.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE:
Computer Aided CME Tracking (CACTus)

PARTICIPANT(S):

Eva Robbrecht
David Berghmans
Gareth Lawrence
Ronald Van der Linden

CONSORTIUM INSTITUTION(S):
Royal Observatory of Belgium

GOAL FOR THE FINAL PRODUCT:
We aim at a processing pipeline that can automatically produce a CME catalogue, each CME listed with its main parameters including time of occurrence, angular span and speed. This tool will be able to run in near-real time on quicklook coronagraphic images as well as beacon mode data and produce near-real time CME warnings. When given input data from a level-1 archive the tool will be able to produce CME catalogues that can be used as a starting point for scientific analysis. Statistics will be published on the succes rate of the tool as compared to CME catalogues produced by human operators.

PROGRESS TO DATE:
A first version of CACTus has been finalised and is currently running in near-real time on quicklook LASCO C2 and C3 images. Please consult http://sidc.oma.be/cactus for futher information on the current version, as well as its current real time output.

FUTURE PLAN OF WORK:
-We are finalising a research paper on the current version that compares the succes rate of CACTUS as compared to classical CME catalogues. The results are very encouraging. The time cadence of the incoming data are the critical factor determining the succes rate.
-Different subroutines of CACTUS will be significantly improved in the coming year, it is expected that this will further improve the succes rate.
-We will investigate the possibility to automatically determine acceleration or deceleration.
-We will investigate the possibility to run CACTus on heliospheric images.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE:
Computer Aided EIT Wave & Dimming Detection

PARTICIPANT(S):
Olena Podladchikova
David Berghmans
Andrei Zhukov

CONSORTIUM INSTITUTION(S):

Royal Observatory of Belgium

GOAL FOR THE FINAL PRODUCT:
We aim at a processing pipeline that can automatically produce a catalogue of EIT waves and dimming regions, each listed with its main parameters such as time of occurence and location. This tool will be able to run in near-real time on quicklook EUVI images as well as beacon mode data and produce near-real time warnings. When given input data from a level-1 archive the tool will be able to produce catalogues that can be used as a starting point for scientific analysis. Statistics will be published on the succes rate of the tool.

PROGRESS TO DATE:
This tool will be partly based on the experience gained with the CACTus tool. Specific developments for the detection of EIT waves and dimming will start soon and will use EIT data as benchmark.

FUTURE PLAN OF WORK:
We aim at a proof-of-principle by the end of 2004. After that, the method will be inserted in a processing pipeline that selects adequate data and preprocesses it. The experience with CACTus shows that much effort is required to make the method robust enough in a near-real time context.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE:
Solar Weather Browser (SWB)

PARTICIPANT(S):
Bogdan Nicula
David Berghmans
Ronald Van der Linden

CONSORTIUM INSTITUTION(S):
Royal Observatory of Belgium

GOAL FOR THE FINAL PRODUCT:
We aim at a tool that can easily display solar images and interpreted context information without the need of having software like IDL and SolarSoft or the need to have background knowledge on FITS files or telescope specific issues. The tool will take the appearance of a browser (think of Internet Explorer) with drop down menu's in which the user can select a date and a type of image, as well as different overlays that provide interpreted context information. These overlays can include information as diverse as NOAA active region numbering, past flare occurence, location of coronal holes or the position of the heliospheric current sheet. The tool will fetch the data over the web from 1 or more dedicated servers were the images and overlays are preprocessed and made

available in a highly compressed format. This, together with intelligent caching at the user side, makes that the 'Solar Weather Browser' will be a fast access to a variety of solar data.

PROGRESS TO DATE:
A first version of the Solar Weather Browser is currently in a beta version test. Versions of the SWB are being finalised for MS Windows, Max OS-X and Unix/Linux. This first version will be released at the website http://sidc.oma.be/SWB in a few weeks.

FUTURE PLAN OF WORK:
The upcoming version of the Solar Weather Browser will be based on EIT & MDI images as well as information from ground-based observatories. In next version, we will include issues specific for STEREO such as red/blue encoding of depth information. Other issues that are considered are movie capabilities and clickable links that bring up access points to the source data.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE:
(Apparent) velocity map construction

PARTICIPANT(S):
Jean-Francois Hochedez
Samuel Gissot

CONSORTIUM INSTITUTION(S):
Royal Observatory of Belgium

GOAL FOR THE FINAL PRODUCT:
We aim at providing a full motion analysis software of EUV and coronagraph image sequences using optical flow techniques. In particular, our algorithm will give a flow map for each image of any sequence given as input. Among the possible applications are:

- Tracking and new visualization tools for tracked coronal features
- Detection of CME initiation and EIT-waves.
- From the flow maps, we make a stereoscopic reconstruction. This tool will be particularly useful at the beginning of the STEREO mission (low separation angle), where a very good correspondance between the two points of view will be achievable.
  LASCO data:
- We will refine our analysis of the velocity map and the deformations of the CMEs occuring during the LASCO sequences.
- Post-processing of the velocity maps will lead to flags or warnings for fast moving objects (typically C2 CME propagation).

PROGRESS TO DATE:

- Examples of EIT CME Watch (19.5 nm) sequences are already successfully analyzed. We are improving the robustness of the algorithm so that we get a fully reliable flow maps with further scientific interpretation. Similar examples of sequences at 30.4 nm have been achieved.
- Velocity maps of LASCO images are already computed with a high confidence level.

FUTURE PLAN OF WORK:

- We are developping and finalizing a software that can process any sequence of images of the regular CME Watch observation mode of EIT. An equivalent algorithm is under development for LASCO sequences. We are improving the robustness of the algorithm for further physical interpretation of the velocity maps.
- We are currently writing a paper describing the principle of our optical flow algorithm.
- A second paper will be submitted afterwards, that will present the physical interpretation of our reliable velocity maps and feature tracking.
- Extension of LASCO-velocity map algorithm to STEREO COR1, COR2 and HI images: we will be able to do an efficient reconstruction of the 3D velocity map of a CME from the 2D velocity maps given by the two STEREO spacecrafts.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE
Automatic solar feature recognition and classification

PARTICIPANT(S)
Dave Rust, Pietro Bernasconi, Barry LaBonte

CONSORTIUM INSTITUTION(S)
JHU/APL

GOAL FOR THE FINAL PRODUCT
A web-based tool for automatically finding and characterizing solar filaments and sigmoids (and possibly CMEs) in solar images

PROGRESS TO DATE
We have developed a program that analyzes Yohkoh, EIT and NOAA GOES x-ray images and is capable of identifying sigmoids. A completely different program has been developed to operate on BBSO H-alpha images and identify solar filaments. This program also characterizes their chirality (right or left handedness). Although this work was undertaken for a space weather forecast program, its application to STEREO is fairly obvious. Before one can begin to

analyze the 3D structure of interesting features, one must reliably identify them in an objective way.

FUTURE PLAN OF WORK

The error rate is still high and we intend to refine the programs to reduce that. Also we intend to extend the programs to work with series of images to determine when, for example, sigmoids develop or brighten and when filaments become activated and disappear. A particular science goal is to characterize the solar features with respect to the parameters of their magnetic helicity, namely, the twist and writhe. Helicity is inherently a 3D feature and extracting it from solar images will be a challenge, but it is important because tracking the build up of helicity and the onset of writhe will probably give considerable insight into the flare/CME process.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE
Reconstruction of coronal magnetic fields (LINFF, NONLINFF)

PARTICIPANT(S)
Thomas Wiegelmann and Bernd Inhester

CONSORTIUM INSTITUTION(S)
Max-Planck-Institut fuer Aeronomie (MPAE)
The institute will be renamed in summer 2004 to:
Max-Planck -Institute for Solar System Research (MPS)

GOAL FOR THE FINAL PRODUCT

The final program reconstructs the 3D coronal magnetic field from boundary data. As input the code uses photospheric magnetic field measurements from various line-of sight and vector magnetographs (e.g. SOHO/MDI, Kitt Peak, SOLIS, Solar-B).

The coronal magnetic field is reconstructed from these boundary magnetic field data and optical observations with SOHO/EIT and later with STEREO/EUVI from both spacecrafts. The program has interfaces to provide the reconstructed coronal magnetic field for tomography and stereoscopy.

The final program package may contain a so-called magnetic stereoscopy tool, which uses photospheric magnetic field data and coronal optical data for a consistent reconstruction of 3D coronal loops.

PROGRESS TO DATE

1) We developed a potential and a linear force free field solver. Both methods use the line of sight photospheric magnetic field as input. This part of our

program is finished and has been tested with SOHO/MDI and Kitt Peak data.

2) A code to align magnetic field lines with observed plasma structures within the linear force free approach. 2D projections of the 3D magnetic field lines are compared with the emitting plasma from optical coronal observations. The code has been tested with SOHO/MDI and SOHO/EIT data (for one viewpoint) and with model data (for two viewpoints).

3) We developed an optimization code for the computation of nonlinear force free magnetic fields. The code requires vector magnetograph data as input. We tested the program with help of a model active region. As the STEREO payload includes no vector magnetograph, we contacted the scientist from SOLIS and Solar-B in order to get data from these instruments.

4) The optimization code was extended for the computation of magneto-hydrostatic equilibria. This code requires vector magnetograph data and tomographic information regarding the coronal density structure as input. The program has been tested with analytic magnetohydrostatic equilibria.

FUTURE PLAN OF WORK

We started to develop a multigrid Grad-Rubin solver for nonlinear force free fields as an additional tool for force free magnetic fields. We are planning to reconstruct nonlinear force free coronal magnetic fields with data from SOLIS in future. (The ground based vector magnetograph SOLIS is running already, but still has some calibration problems.) We are planning to improve the magnetic stereoscopy program, e.g. regarding a better tracing of coronal loops in EIT data.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE
Real-time and 3D Visualization of STEREO images

PARTICIPANT(S)
Volker Bothmer, Thomas Kraupe, Rainer Schwenn, Borut Podlipnik, Hebe Cremades and Thomas Wiegelmann

CONSORTIUM INSTITUTION(S)
Max-Planck-Institut für Sonnensystemforschung (MPS)*
*Formerly Max-Planck-Institut für Aeronomie (MPAe)
Germany

GOAL FOR THE FINAL PRODUCT

We aim to establish a real-time display of STEREO images on flat LCD screens in the main entrance hall of the Planetarium Hamburg

(www.planetarium-hamburg.de) as well as facilities for 3D visualization. Of special interest are displays under the Planetarium dome. Hamburg currently has the most modern Planetarium of the world. The historic building, located in a park, has been renovated in 2003. The reopening occurred in October 2003. The Planetarium is visited by about 1000 people each weekend and serves as an ideal place for EPO activities. A permanent information package will be established to introduce the STEREO mission.

PROGRESS TO DATE

A software code and hardware package has been developed at MPAe that allows 3D visualization of the solar corona at EUV wavelengths based on SOHO/EIT images. The software coded uses SOHO EUV images as input. The 3D display works best with images overlaid that were taken with a time difference of 8 hours which corresponds to two viewing angles separated by about 5 degree. The simultaneous observations taken by the SECCHI imaging package on the STEREO spacecraft at different vantage points will provide for the first time the possibility to observe also the dynamic corona in 3D. The hardware comprises suitably equipped workstations (graphic cards, memory, disks), special monitors (120 Hz mode) and Stereographic LCD glasses. The visualization set, together with information plates on the STEREO mission, can be transported to special exhibitions for demonstration purposes, e.g. for a gala event at the Planetarium Hamburg in 2002. Here for the first time a full solar rotation at maximum resolution has been displayed in 3D based on EIT 195 Å images for a time interval in early 2002. A 3D animation of the solar magnetic field has been established for the same time interval. The visualization has been successfully presented at various German locations in 2003.

FUTURE PLAN OF WORK

We aim to complete preparations for real-time display and 3D visualization facilities at the Planetarium Hamburg, including a permanent STEREO information package until about launch time (early 2006). Various Education and Public Outreach (EPO) activities on 3D visualization and the STEREO mission will continue until launch. A collaboration with a German high school near Hamburg which is introducing H-alpha observations at this school is under investigation.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE

3D Structure of CMEs: Origin, Internal Magnetic Field Configuration and Near-Sun Evolution

PARTICIPANT(S)

Volker Bothmer, Hebe Cremades and Durgesh Kumar Tripathi

CONSORTIUM INSTITUTION(S)
Max-Planck-Institut für Sonnensystemforschung (MPS)*
*Formerly Max-Planck-Institut für Aeronomie (MPAe)
Germany

GOAL FOR THE FINAL PRODUCT

We aim to establish a computer code that allows to directly test with help of the images received from STEREO SECCHI, whether the 3D structure of CMEs, their internal magnetic field configuration and near-Sun evolution matches the model predictions proposed by Cremades & Bothmer and Tripathi & Cremades & Bothmer based on a detailed analysis of SOHO/LASCO/EIT/MDI observations published in Astronomy & Astrophysics 2004. According to the presented scheme, the basic characteristics of CMEs can be deduced from correlated analyses of photospheric magnetic field, low coronal EUV and chromospheric H-alpha data by taking into account self-similar MHD expansion, pre- post coronal CME phenomena like flares, EUV dimmings, waves or arcades and the ambient coronal structure. As input data the code uses solar disk magnetic field and H-alpha observations from ground-based observatories and EUV images provided by the STEREO SECCHI Extreme Ultraviolet Imagers (EUVIs) to identify the CME source region. If possible SOHO/EIT or SDO/AIA measurements will be taken into account. The relevance of the EUV images as input parameters for the software code will depend on the changing perspectives with respect to the CME s place of origin. As output, the software code will yield the presumable 3D structure and evolution of CMEs for the distance range from about 1.5 to 6 solar radii. This synthetic 3D reconstruction of CMEs can directly be compared with the CMEs observations provided by the SECCHI COR 1 and COR 2 coronagraphs on board STEREO A and B. The predicted magnetic configuration and orientation of the CME inferred from the photospheric field and H-alpha data will be tested through in situ measurements of the solar wind and of energetic particles as provided by the STEREO and other suitably equipped and located spacecraft in the inner heliosphere. These studies can be interfaced with Space Weather Models. The comparisons between the model predictions and the observations will also provide information on how sensitive the views of CMEs obtained by the STEREO imagers depend on the different perspectives, i.e. the different viewing angles of the spacecraft reached over the course of the mission.

PROGRESS TO DATE

A detailed and sophisticated analysis of CME observations has been undertaken based on the entire SOHO/LASCO/EIT/MDI database in relationship with ground-based H-alpha observations, including investigations of their solar source regions and characteristics as well as the associated pre- and post-eruption chromospheric and low coronal phenomena. Image analysis was performed primarily with the IDL and ENVI software packages under help of the program libraries that have been established for LASCO/EIT/MDI and in a broader context for the SolarSoft suite. The results of this analysis, which reveal the dependence of the 3D structure of CMEs on their underlying magnetic field source region configuration and their relationship with post-eruptive arcades has been submitted in form of two extended papers to the Astronomy and Astrophysics journal. Both papers are in the refereeing process. It is assumed that camera-ready versions are available in early 2004. The results of the studies will be presented to the community during the next months at the STEREO SWG, ISSI CME WS, SECCHI science meeting, EGU, COSPAR and at the IAU colloquiums related to solar/heliospheric physics. A joint study to visualise the results in 3D which started in March 2003 at JPL had to be stopped when open communications on the project were hampered by ITAR restrictions. However the

CME-visualisation library established by MPAe has been delivered and set up at JPL and can be used to continue this project

FUTURE PLAN OF WORK

We will complete the study on the evolution of the underlying photospheric fields that precede the onset of CMEs, including the fine-scale dynamics of prominence motions and eruptions, and the evolution of post-CME features based on SOHO, TRACE and ground-based observations. The results on the 3D CME structure will be made available to the community as CME-visualization library. A key issue will include further improvements to predict the evolution of the magnetic flux rope structure seen for many CMEs up to the orbits of Earth and Mars. For these purposes solar wind data from ACE and Wind will be studied. Results from two projects funded by the EU and led by V. Bothmer, on the solar and interplanetary sources of geomagnetic storms in solar cycle 23 the EU are being incorporated. The follow up project of the one being just finished has been funded in the time frame of 2004 to 2006. The solar-cycle dependence of the results on the origin, 3D structure and evolution of CMEs is under study as well as a synthetic 3D visualisation of CMEs by using the software package 3DStudioMax. It is aimed that the software code for prediction and real-time comparison of the 3D CME structure will be developed until the end of 2005.

3D Reconstruction and Visualization Team Individual Projects

PROJECT SUMMARY TITLE
Combining Nancay Radio heliograph with SECCHI instruments

PARTICIPANTS
Monique Pick, D. Maia, A. Kerdraon

CONSORTIUM INSTITUTION
LESIA, Observatoire de Paris

GOAL FOR THE FINAL PRODUCT

We project to provide complementary radio imaging observations to the SECCHI instruments (and to S-WAVES). The Nancay Radio heliograph (NRH) provides daily observations of the corona which are obtained quasi-simultaneously at 5 distinct altitudes (typically between 0.1 and 1 solar radius above the photosphere). The overlap of the SECCHI instruments and the NRH will be very useful. We project to compare radio and SECCHI observations to identify, for example, the coronal structures which are emitting in the radio (for example, path of the energetic electron beams). NRH imaging observations can be made for both limb and disk events with high time resolution: we may observe source regions that are on the disk and peak above the occulting disk of the coronagraphs. The high cadence of NRH observations permit us to see the time evolution of the physical processes in the corona and to identify, for example, sites of magnetic interaction and particle acceleration.

One of our main goals will be our contribution for understanding the relationship between CMEs and their terrestrial effects. We project to construct a survey of radio observations that will be used to provide:

- Proxies of CMEs: onset and lateral progression during the early stages of development, identification of regions of magnetic field interaction (on-disk and limb).
- Shock identification.
- Electrons beams and type III bursts.
- Relationship with S-WAVES measurements.

PROGRESS TO DATE

A first version of a daily survey has been established at one frequency (164 MHz, January 1997-mid 2003). This survey also includes the CME occurrence (time, width, projected velocity) detected by LASCO. We have started to use this survey to study the association with CMEs and to define physical parameters and proxies.

FUTURE PLAN of WORK

Test and evolution of the survey to provide an operational product.