An NSF Science and Technology Center led by Boston University, involving solar partners at SAIC, U of Colorado, BU, HAO, Stanford, NRL, AFRL, and UCB

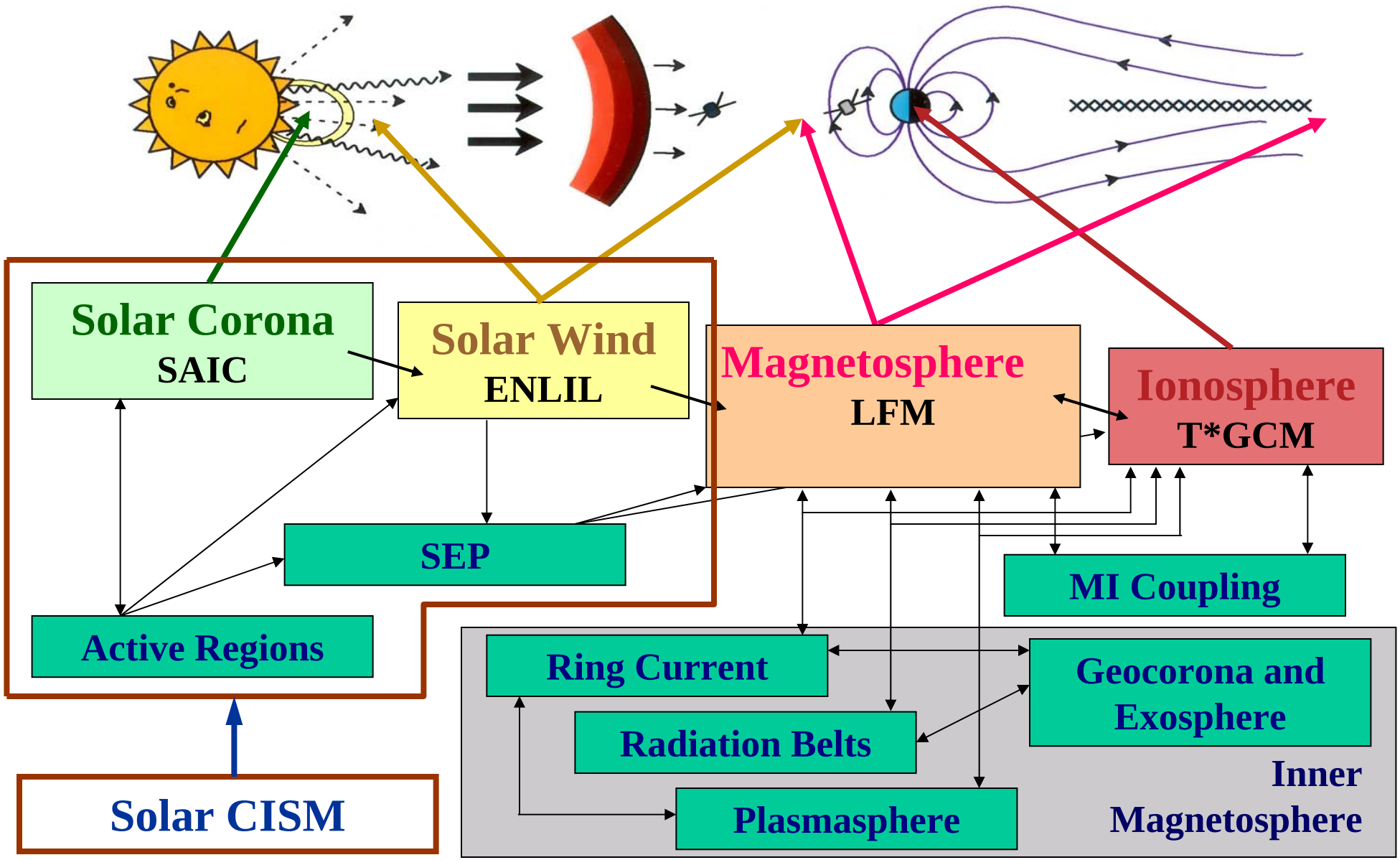
CISM's solar/heliospheric science goals center on the development of a validated, coupled, modular, simulation of the Sun to L1 space, including:

-> a realistic corona and resulting solar wind structure

-> realistic CME initiation and propagation capability

-> a SEP injection and transport scheme that uses the MHD model results

-> solar wind and SEP coupling to geospace


Solar Corona
SAIC
Solar Wind
ENLIL
Magnetosphere
LFM
Ionosphere
T*GCM
SEP
MI Coupling
Active Regions
Ring Current
Geocorona and
Exosphere
Radiation Belts
Inner
Magnetosphere
Plasmasphere
Solar CISM

CISM
CENTER FOR INTEGRATED SPACE WEATHER MODELLING

key areas of progress toward the solar-heliosphere simulations to date

->Developed CORHEL, a coupled MAS (SAIC) corona/ ENLIL (U of Colorado) solar wind MHD simulation with user-friendly interface. Validation is currently underway

-> Carried out an initial, coupled, modular, end-to-end (Sun to Middle Atmosphere) proof-of-concept simulation of an ad-hoc CME event- described in a special issue of JASTP

->Characterized details of realistic CME initiation in selected observations, especially May 12, 1997

- >Adopted a “Cone” Model of CME events for developing a generalized first-order scheme and for interplanetary propagation and SEP code development

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key goals in solar/heliosphere areas

-> Archived Codes capable of providing regular MHD simulations of the quiet corona and solar wind, with documented performance

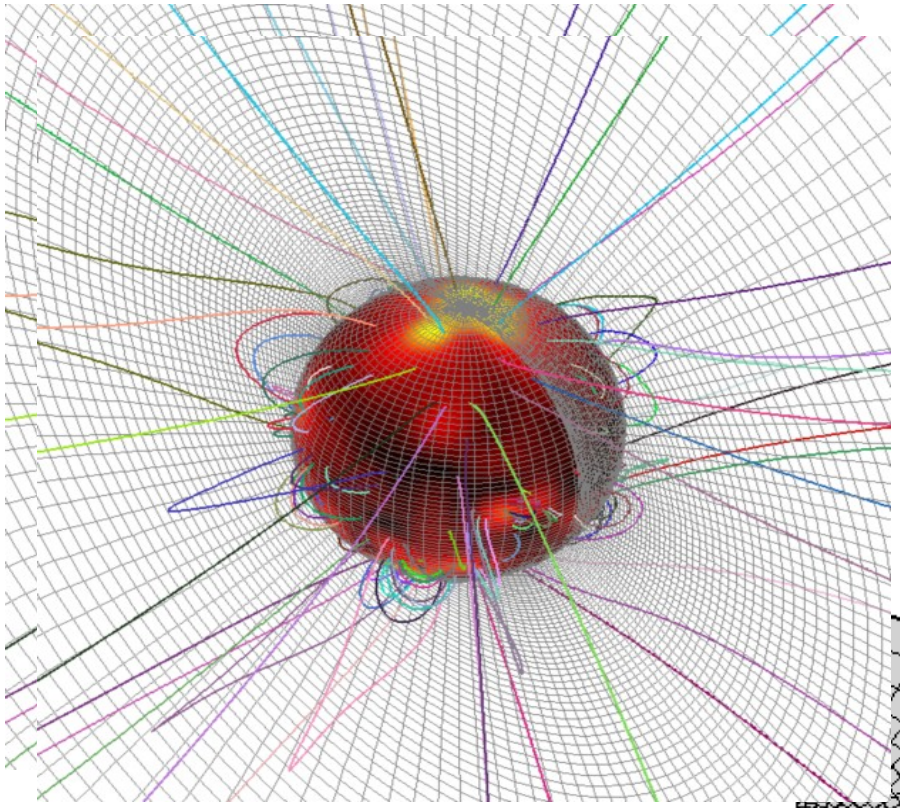
->An archived Cone Model simulation code for CME events, including an integrated SEP code module

-> Documented schemes for observation-based CME initiation and evolution in the inner heliosphere

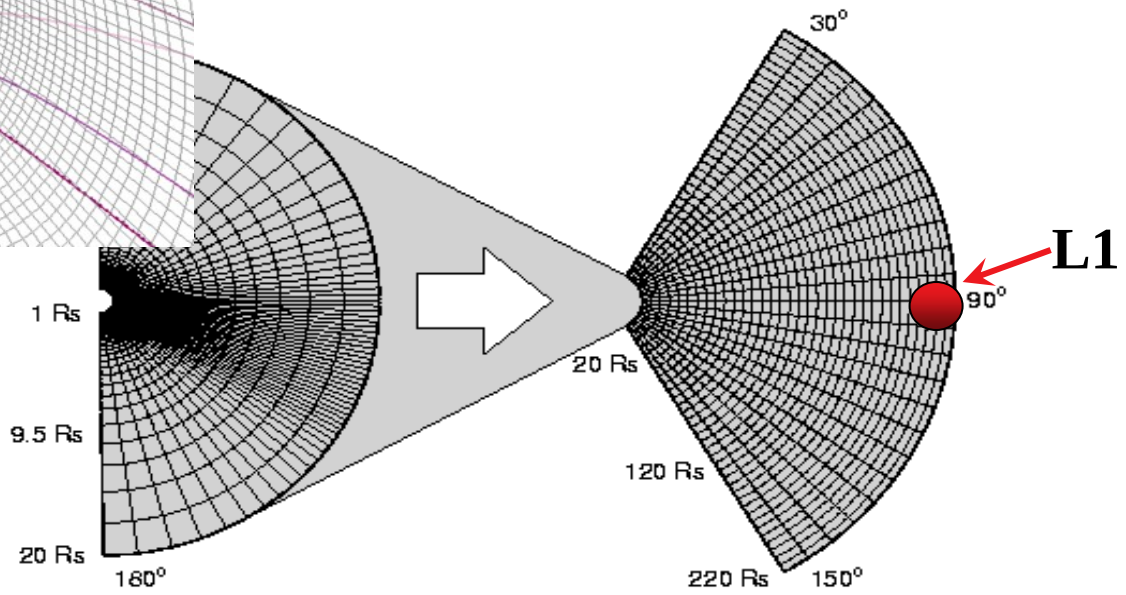
-> Archived Codes for coronal/solar wind/SEP event simulations for examples with realistic CME initiation

->A geospace coupler scheme for solar wind, shocks and SEPs

CISM Solar/Heliospheric Code Computational Grids



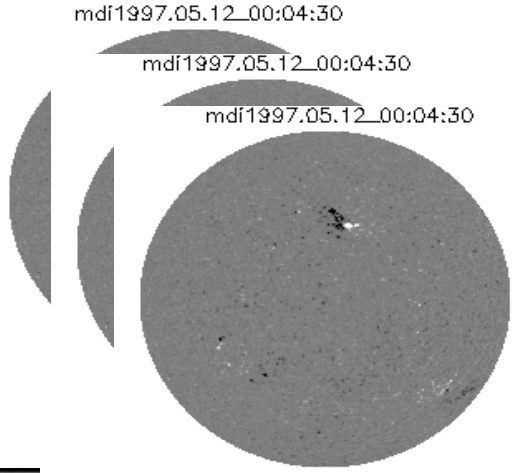
MAS corona grid showing magnetic field lines and solar magnetogram- based boundary field (high spatial resolution segment option for active region resolution)

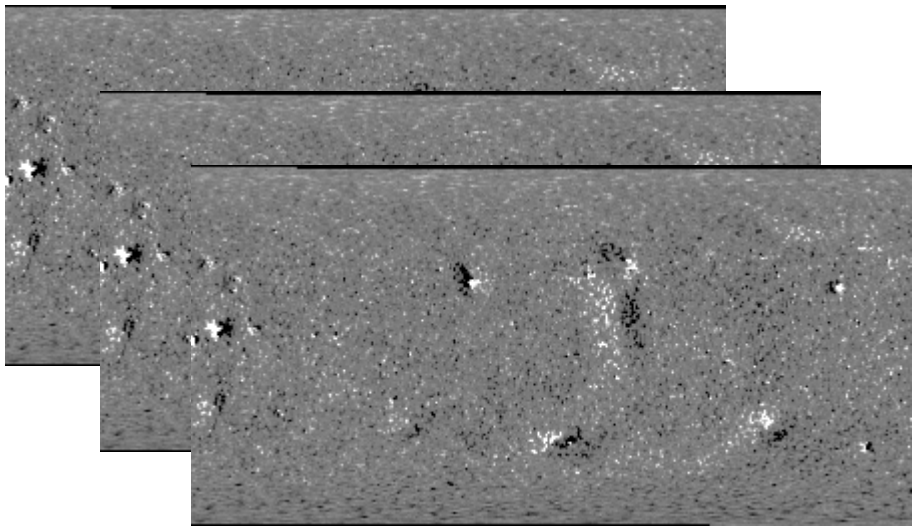


Coupled MAS corona, ENLIL solar wind

Much effort has been expended in evaluating and improving the synoptic field maps used as the inner boundary conditions (e.g. polar corrections)

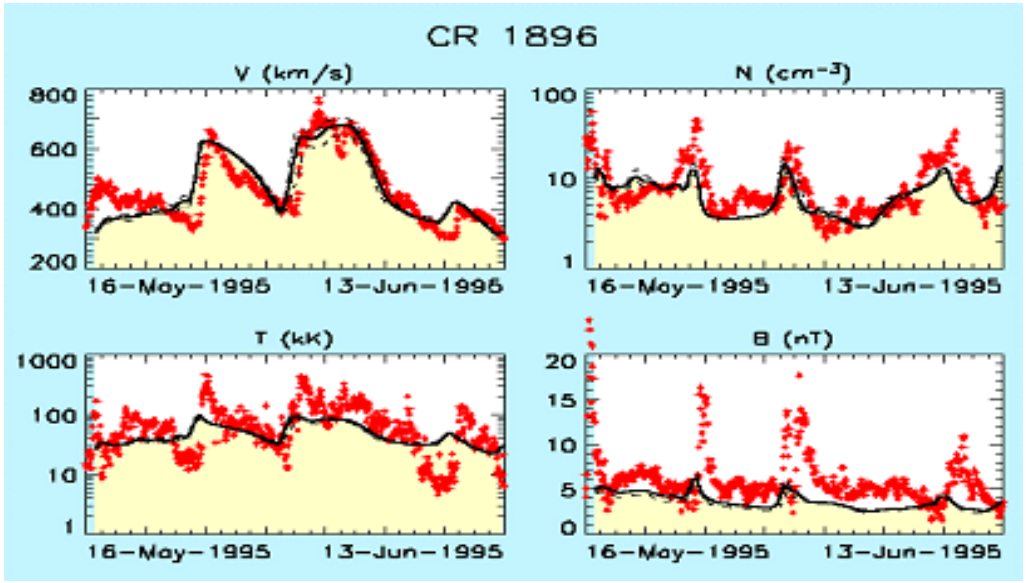
Full-disk data from SOHO MDI or ground based observatories provide most raw data although localized vector mag data are also examined (e.g. CORHEL currently uses NSO, WSO)



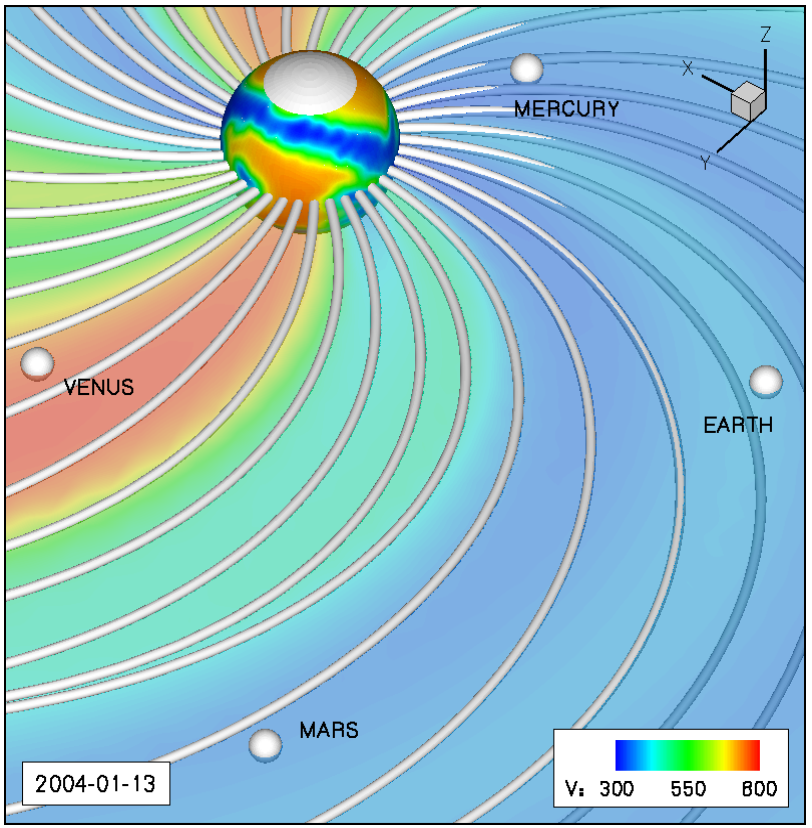


Models use synoptic Field map(s) including: traditional 27-day Carrington, updating fields, or high cadence updating insets

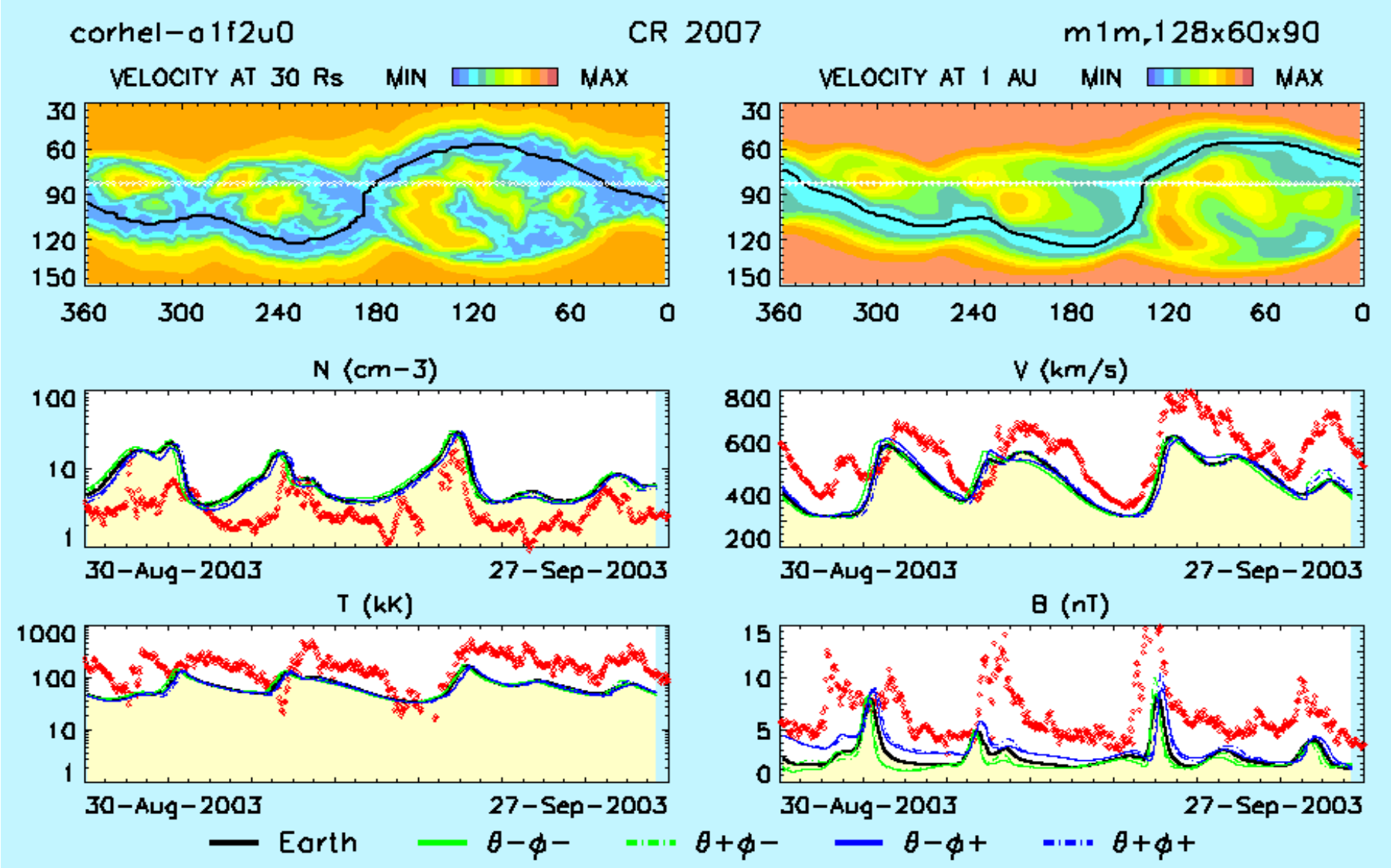
Both in-situ L1 solar wind data comparisons and coronal hole observations are being used to validate the CORHEL simulations of the steady corona and solar wind-The results are sensitive to the details of the synoptic maps used.



(D. Odstrcil images)



e.g. Low latitude hole sources depend on boundary map and code resolution



synoptic map and CORHEL plans

-> CORHEL is being validated against L1 data sets and compared to results from the WSA semi-empirical model and a “hybrid” Model with WSA corona and ENLIL solar wind

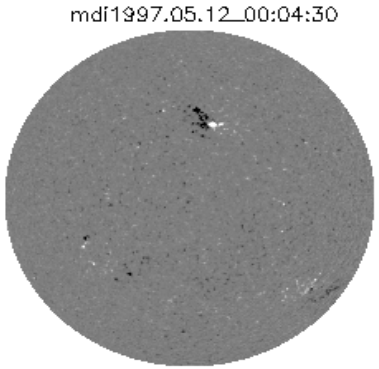
->Improved solar wind heating/acceleration is being added (MAS in current CORHEL version is polytropic)

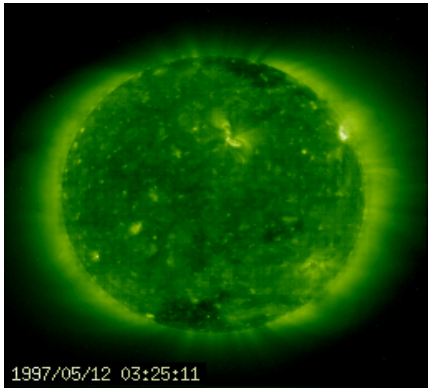
-> CORHEL is being expanded to use a greater variety of synoptic map options (used synoptic maps are part of validated codes)

-> Synoptic map treatments, in particular polar corrections and updates are being tested for performance as boundary conditions

The Halo CME on May 12, 1997 and its associated interplanetary consequences are being used to develop a CISM approach to realistic event simulation

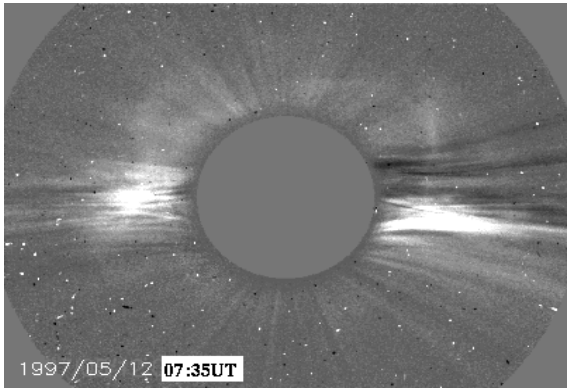
Photospheric field from SOHO MDI

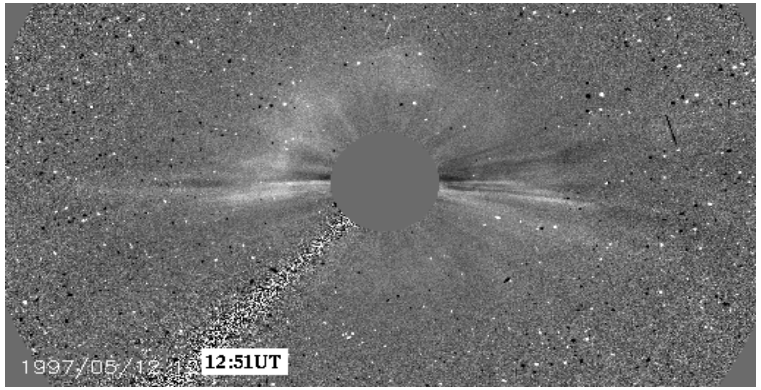


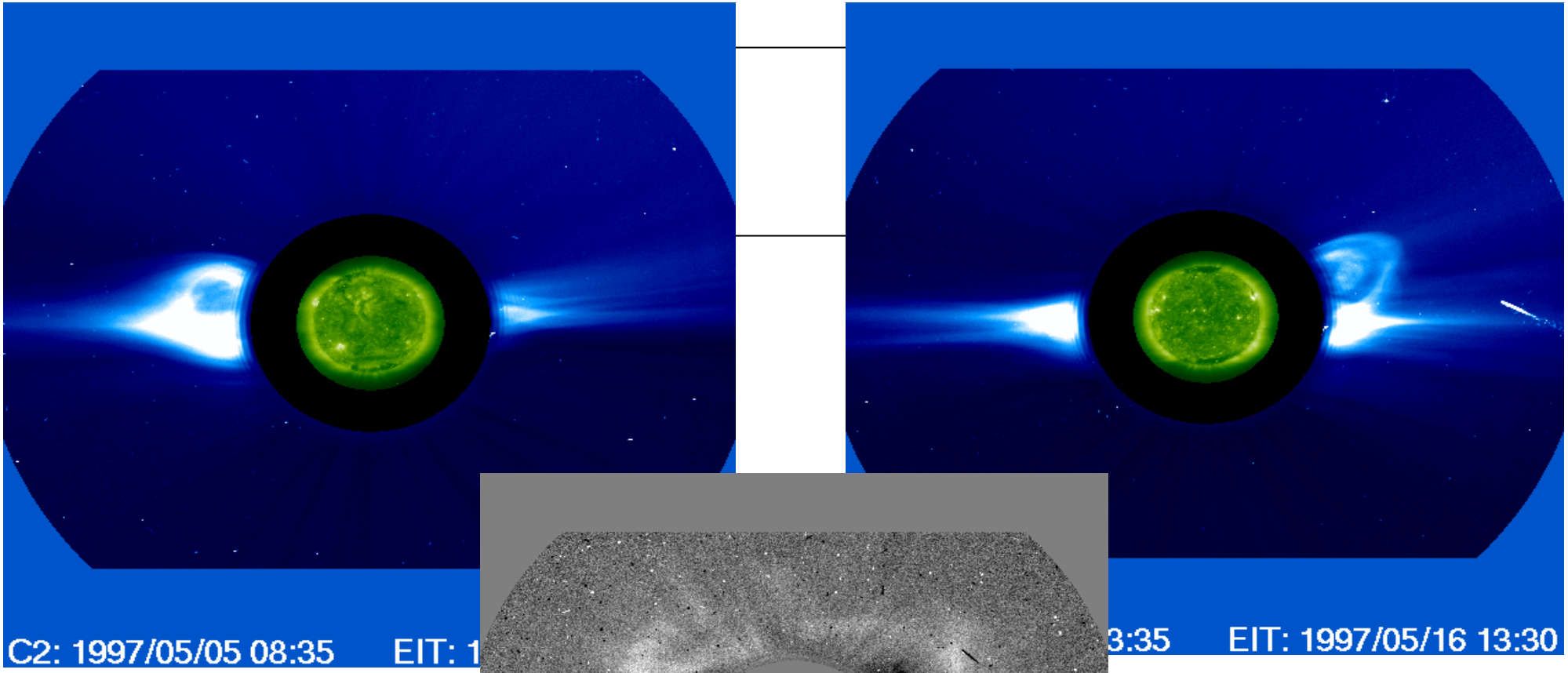


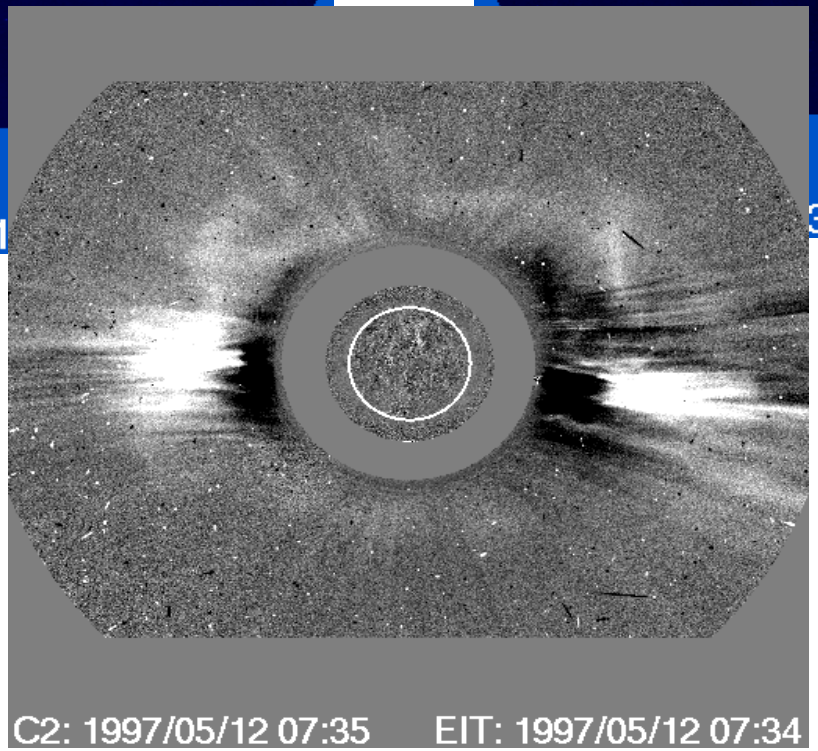
SOHO EIT EUV observations

SOHO LASCO C2 and C3 observations





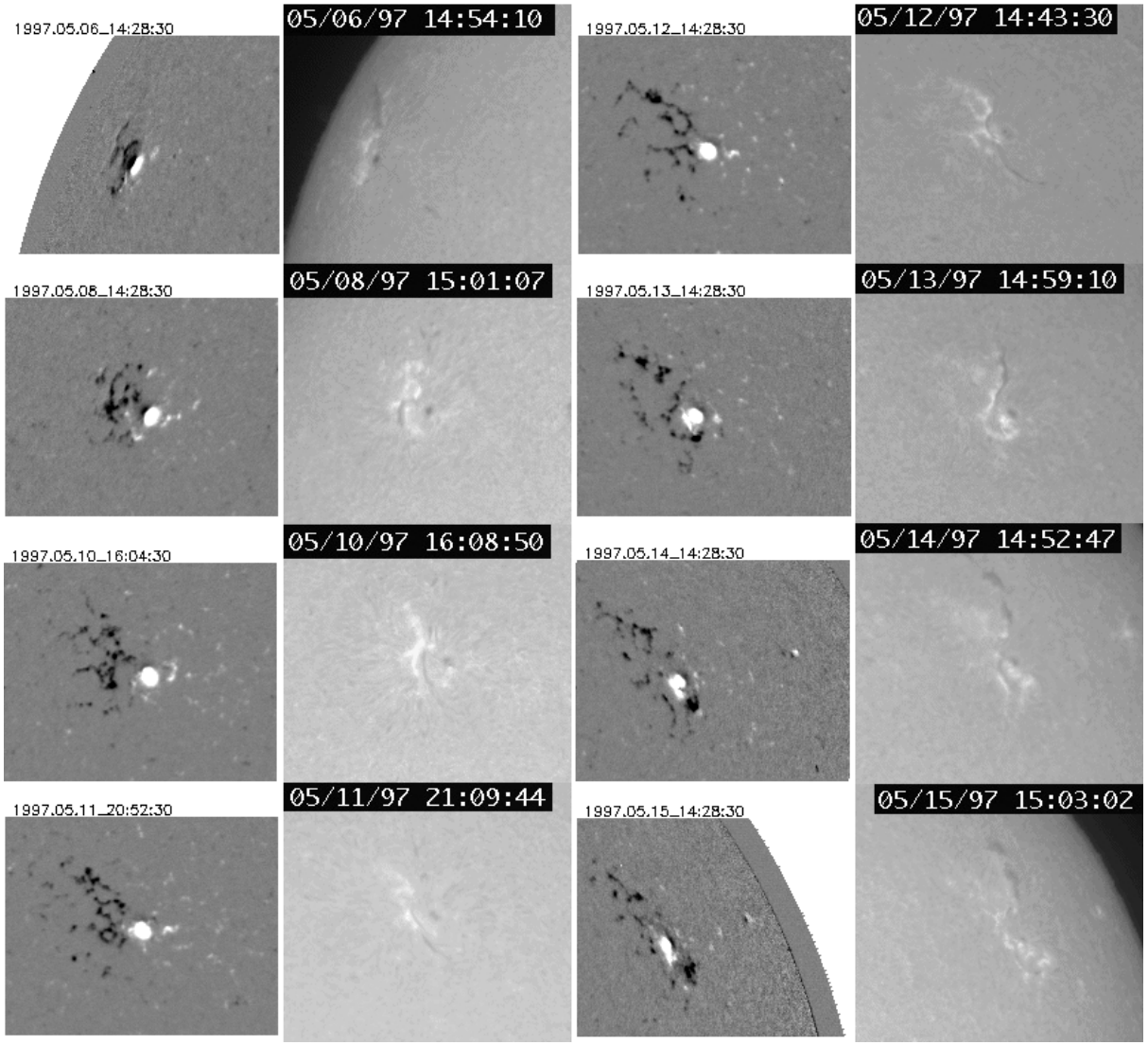




A useful aspect of this event was the observation of similar CMEs on both limbs involving the same active region

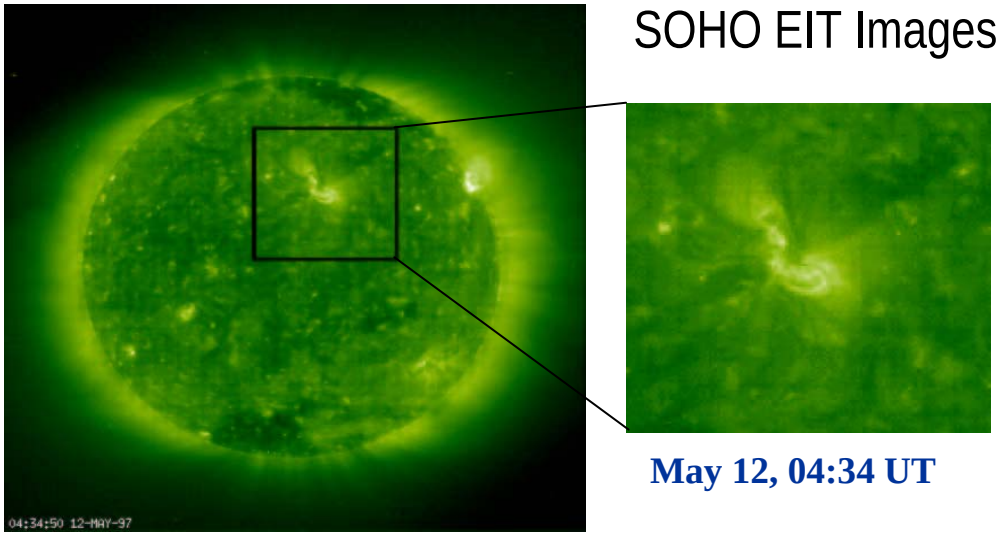
Left to right: May 5, May 12 halo, May 16 CMEs (SOHO images From S. Yashiro's CDAW CME catalog)

The active region magnetic field evolution was closely examined as well as other signatures of a potentially eruptive site including H-alpha

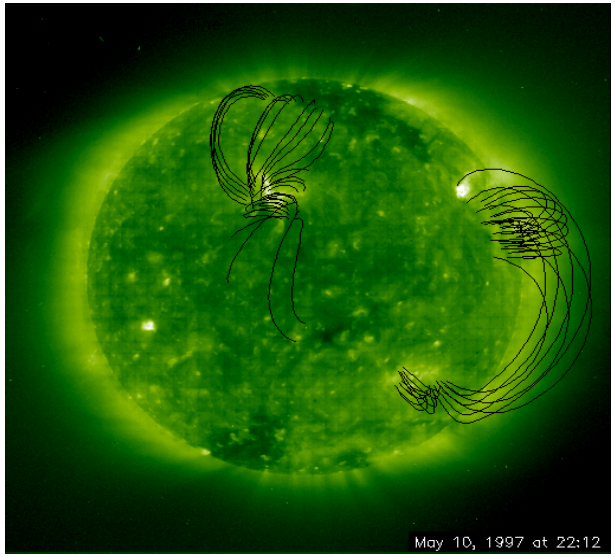


(Y. Li figure)

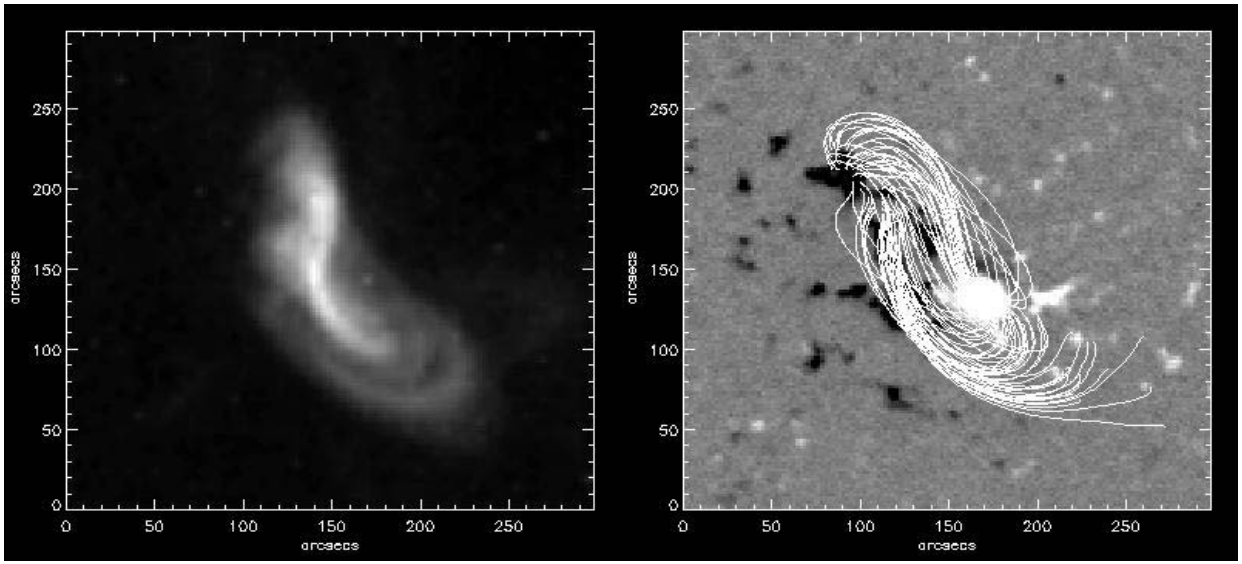
SOHO EIT Images



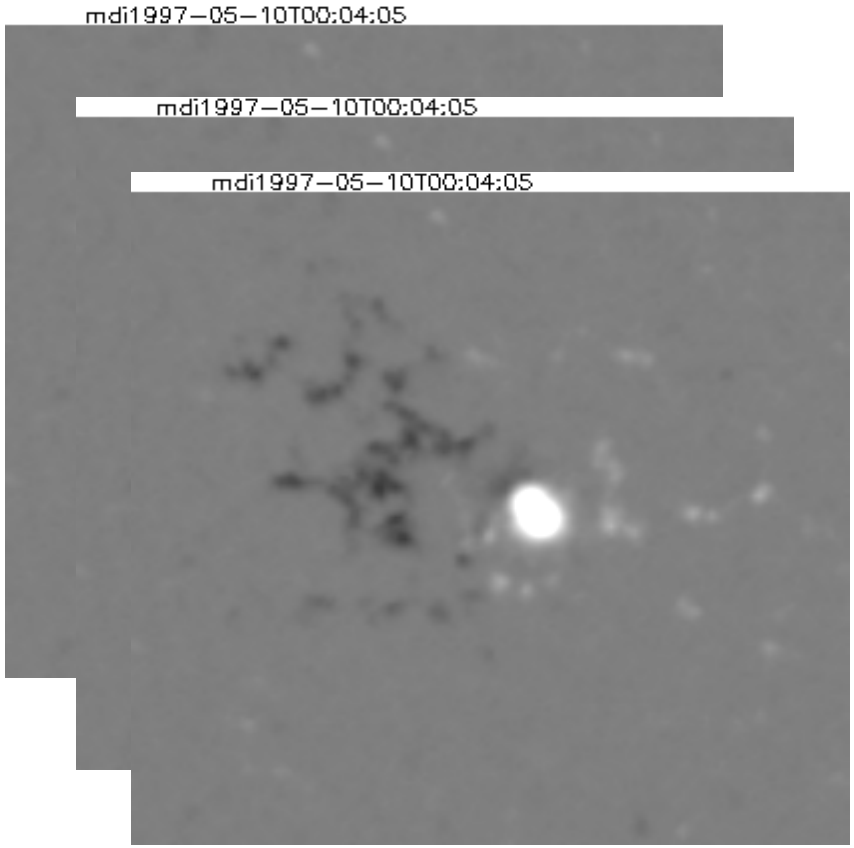
May 12, 04:34 UT

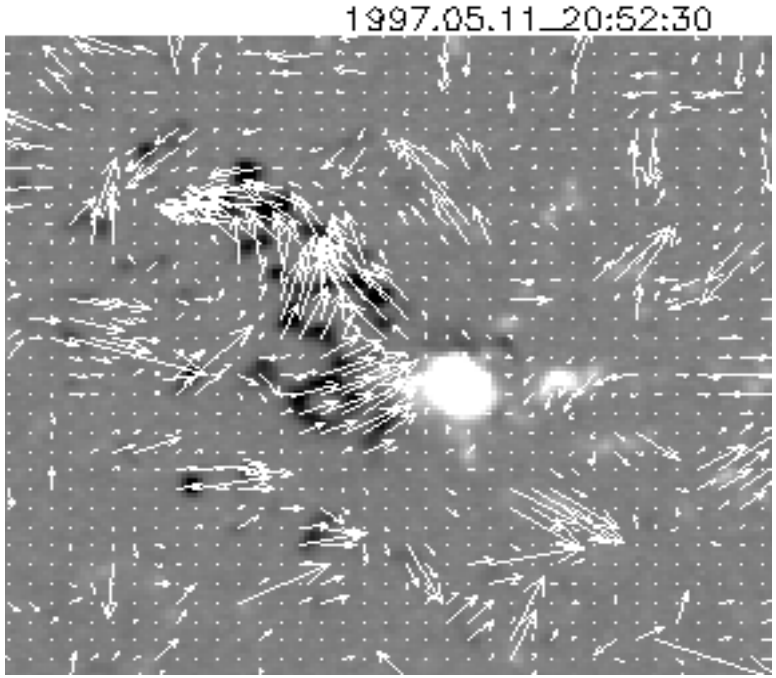


A force-free field model (left) was used to reproduce an SXT soft x-ray image. The PFSS model (above right) suggested the larger scale field context and global connections of the active region. (from Y Liu and Y Li)



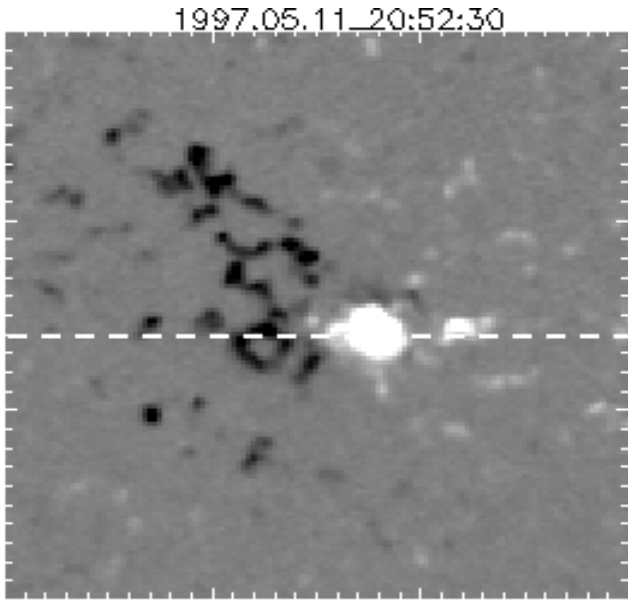
Local Correlation Tracking was used to infer the active region horizontal velocities

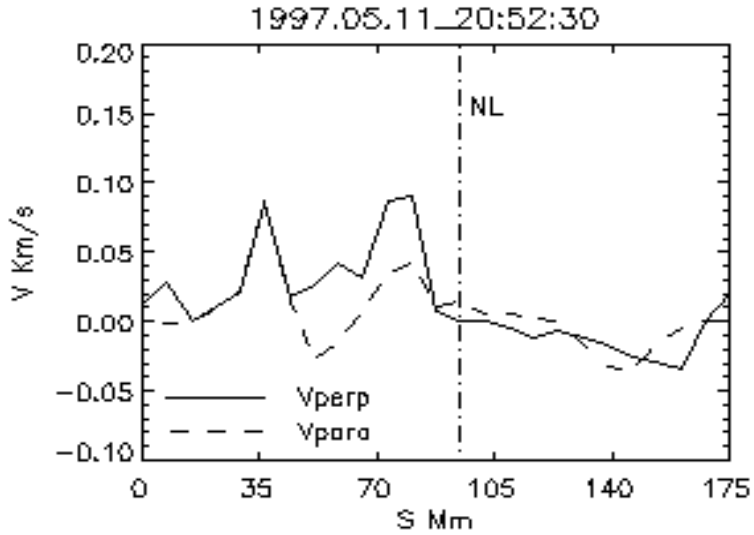


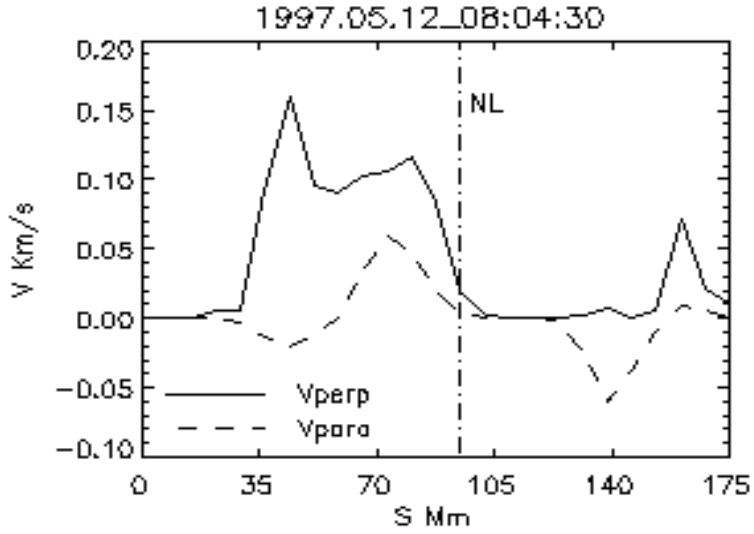


From Y. Li

Inferred flows parallel to and perpendicular to the active region neutral line were found to exhibit shear and convergence, respectively, as required by CME initiation scenarios



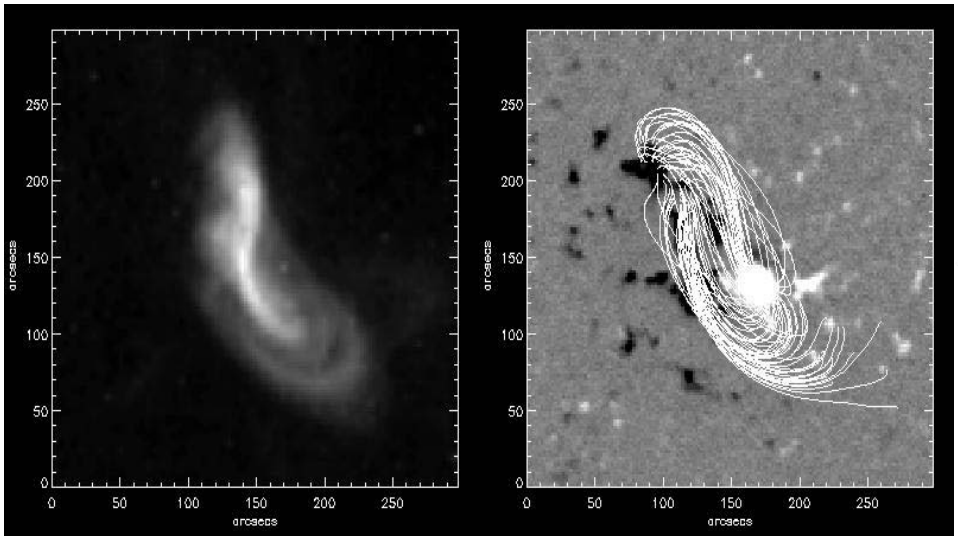


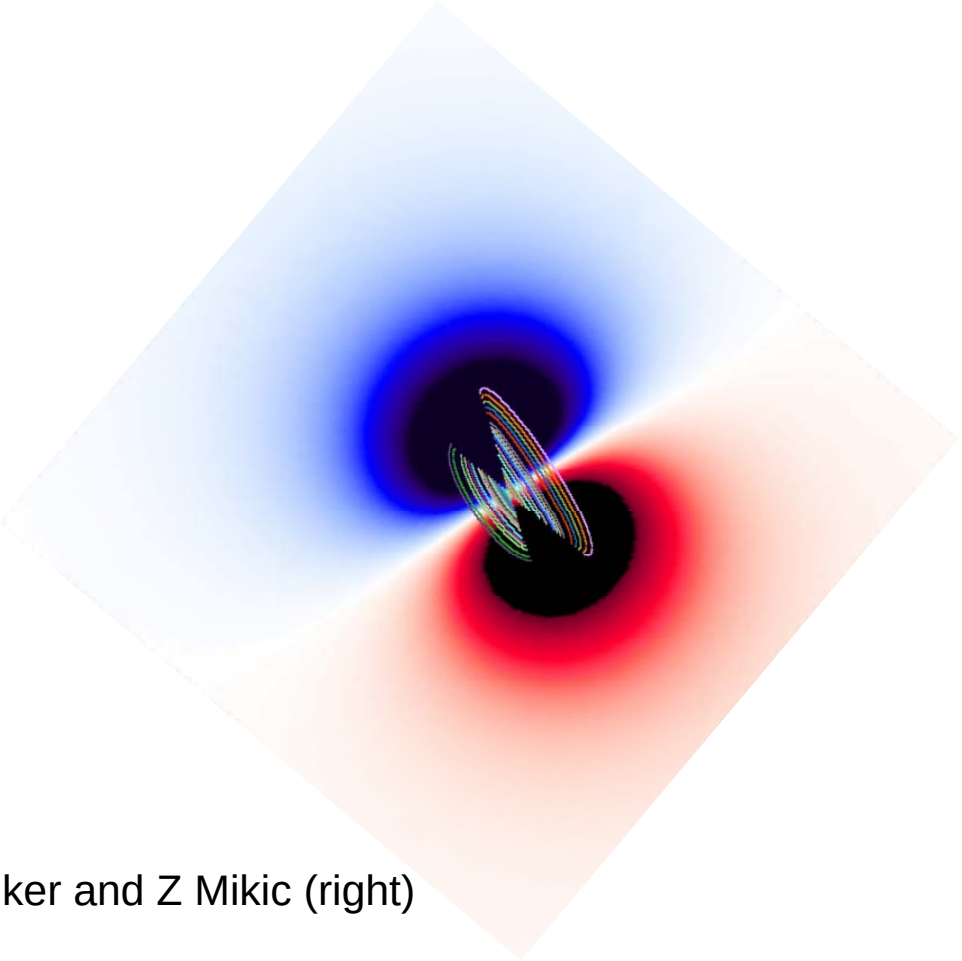


Above: a horizontal cut through the center of the sunspot along which flows are evaluated.

Right- spatial profile of the horizontal velocity component that is perpendicular (Vperp) and parallel (Vpara) to the neutral line (NL)

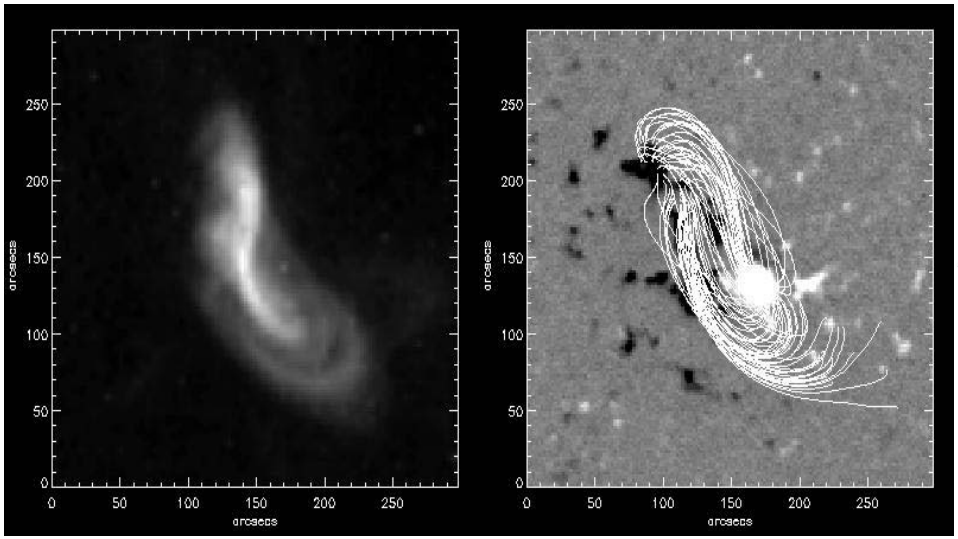
Vortical velocity fields were applied to a bipolar active region in an MHD simulation to produce shear along the neutral line……

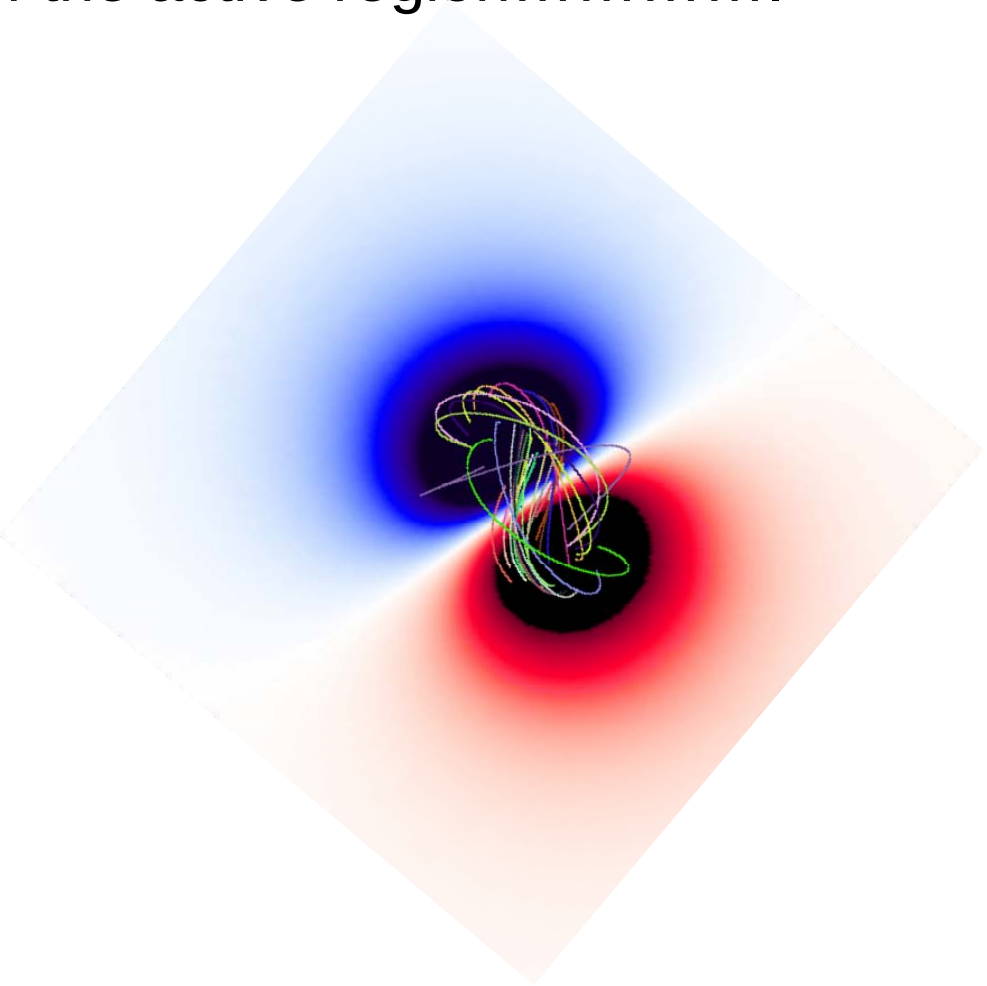




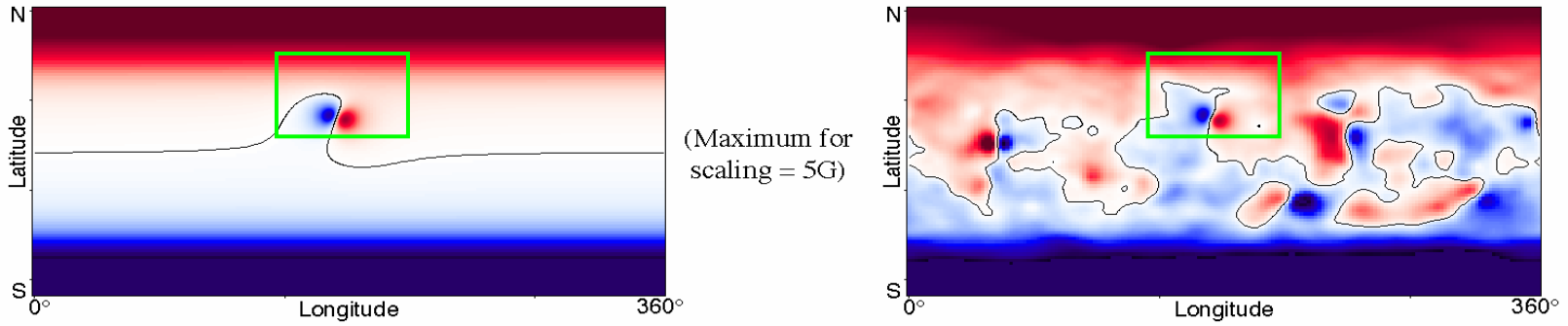
Figures from Y Liu (left), J Linker and Z Mikic (right)

To produce a field line structure resembling the force-free field and the SXT image of the active region……

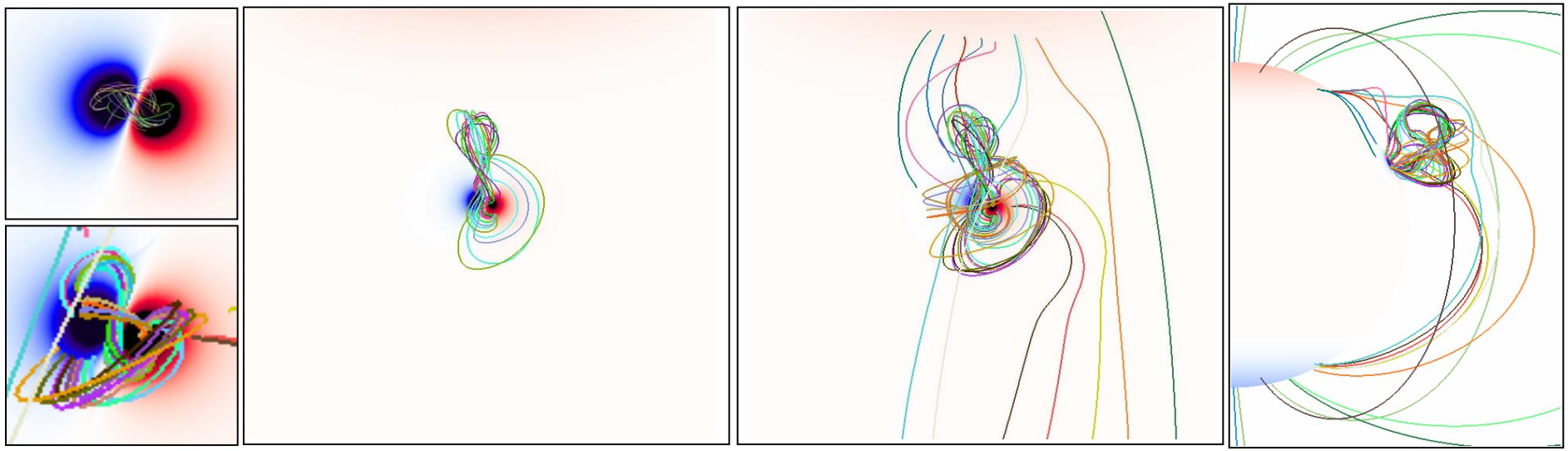




When evolved within the global background field deduced from the observations, followed by flux cancellation (reduction) in the active region, eruption occurs……..

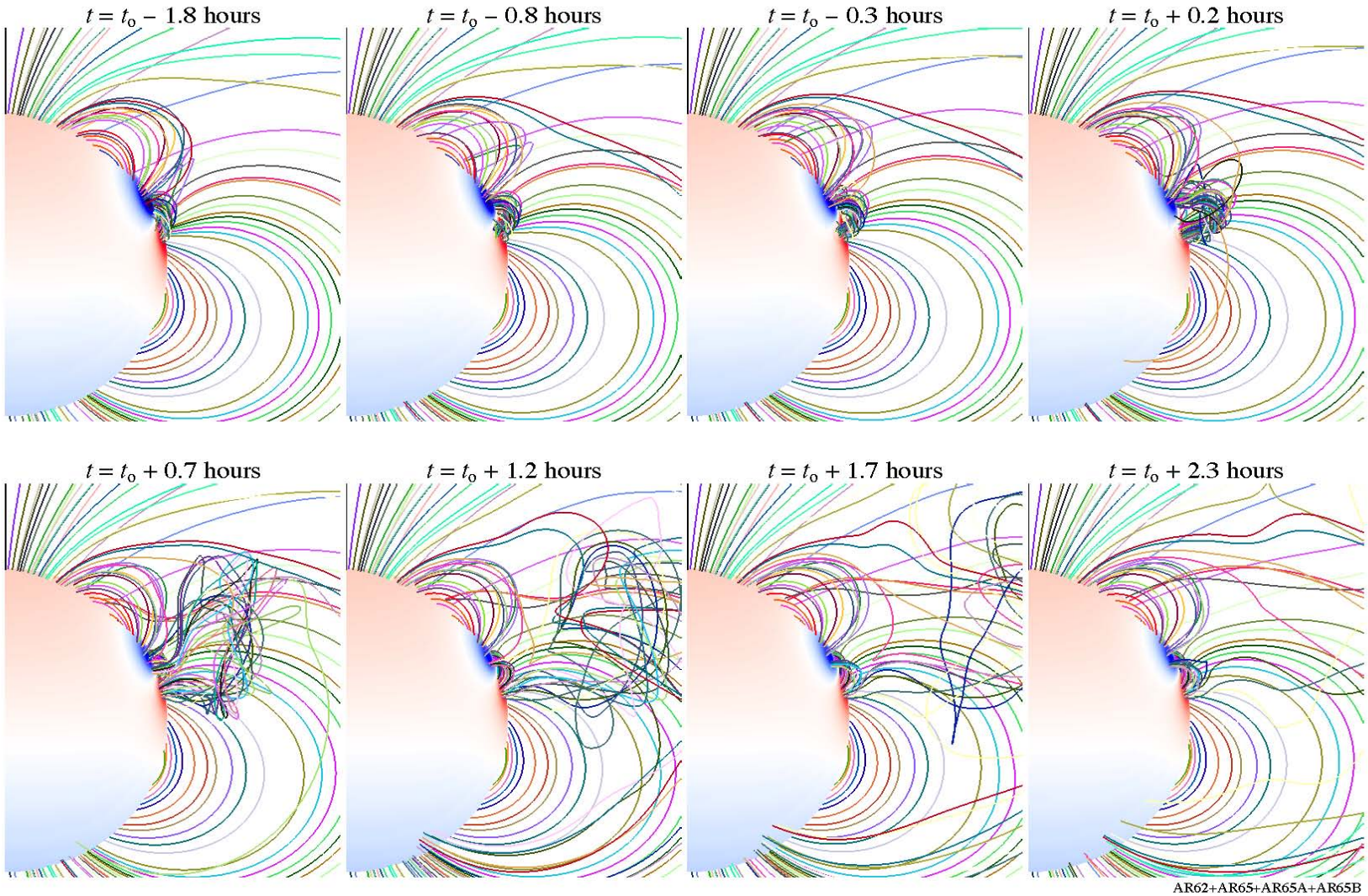


B_r from Potential field for Model flux and MDI data at r = 1.121 R_s



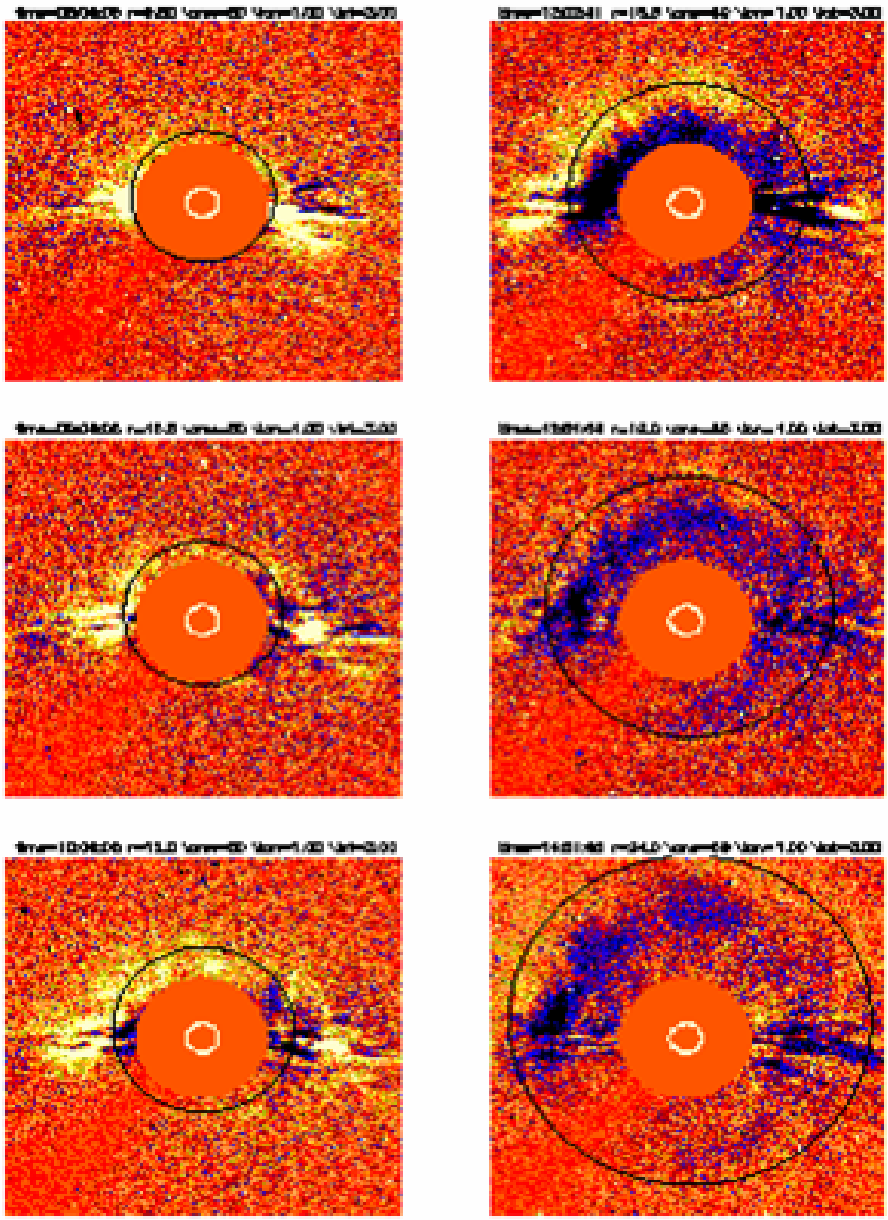
Images from Z. Mikic and J. Linker

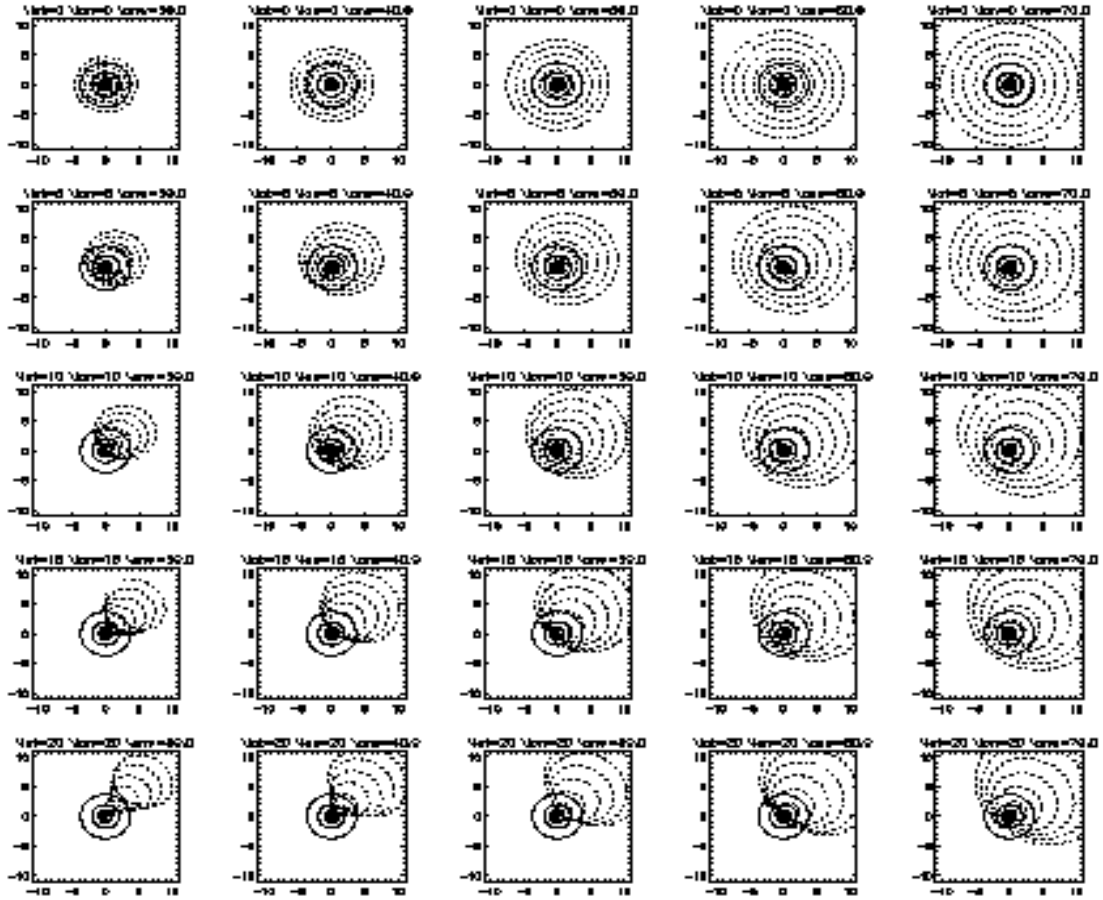
Flux Rope Eruption (Zoomed View)



Still needed: addition of solar wind, interplanetary transport

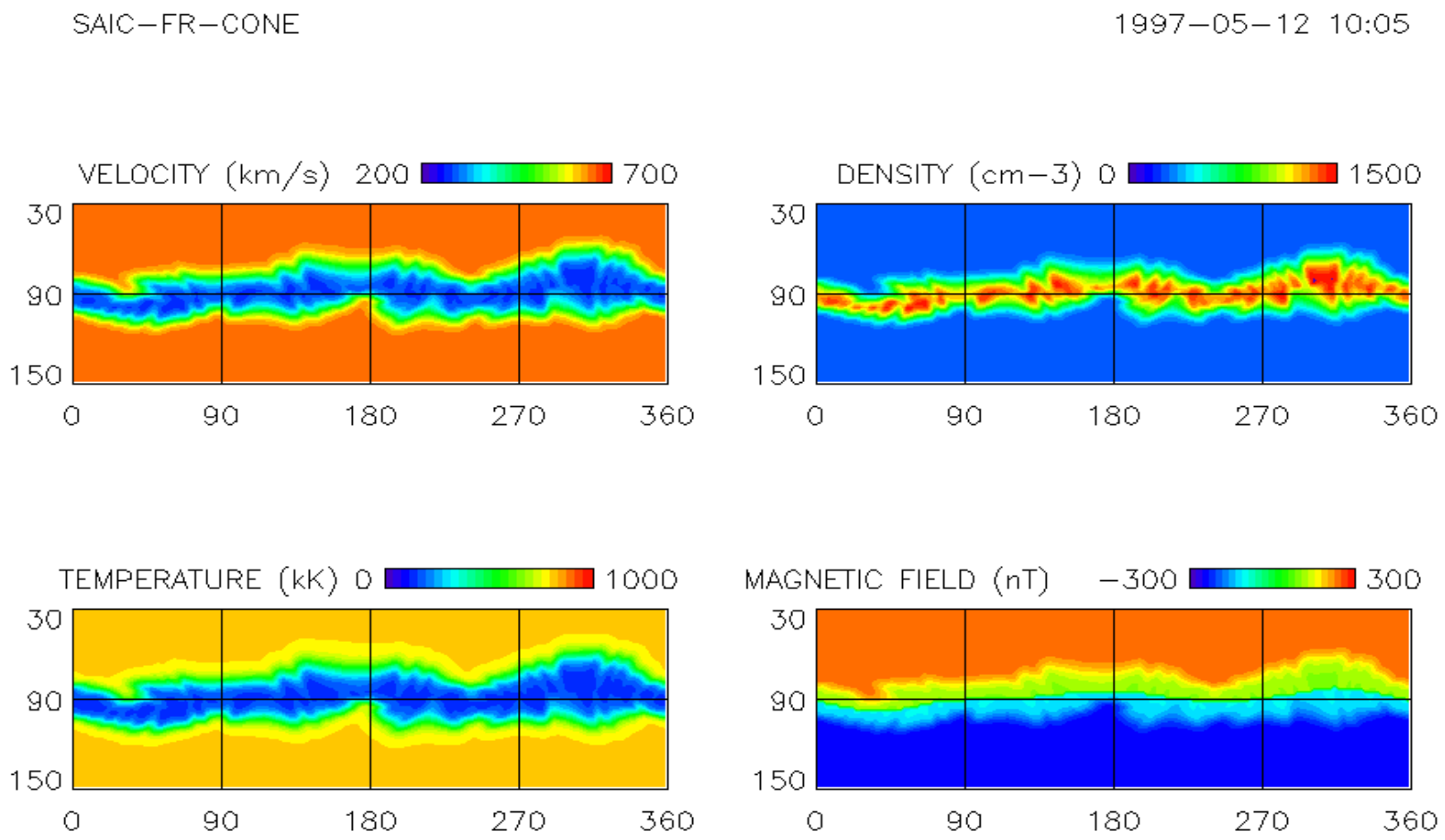
The CME Cone Model –alternative reintroduced by Zhao et al. (2002)





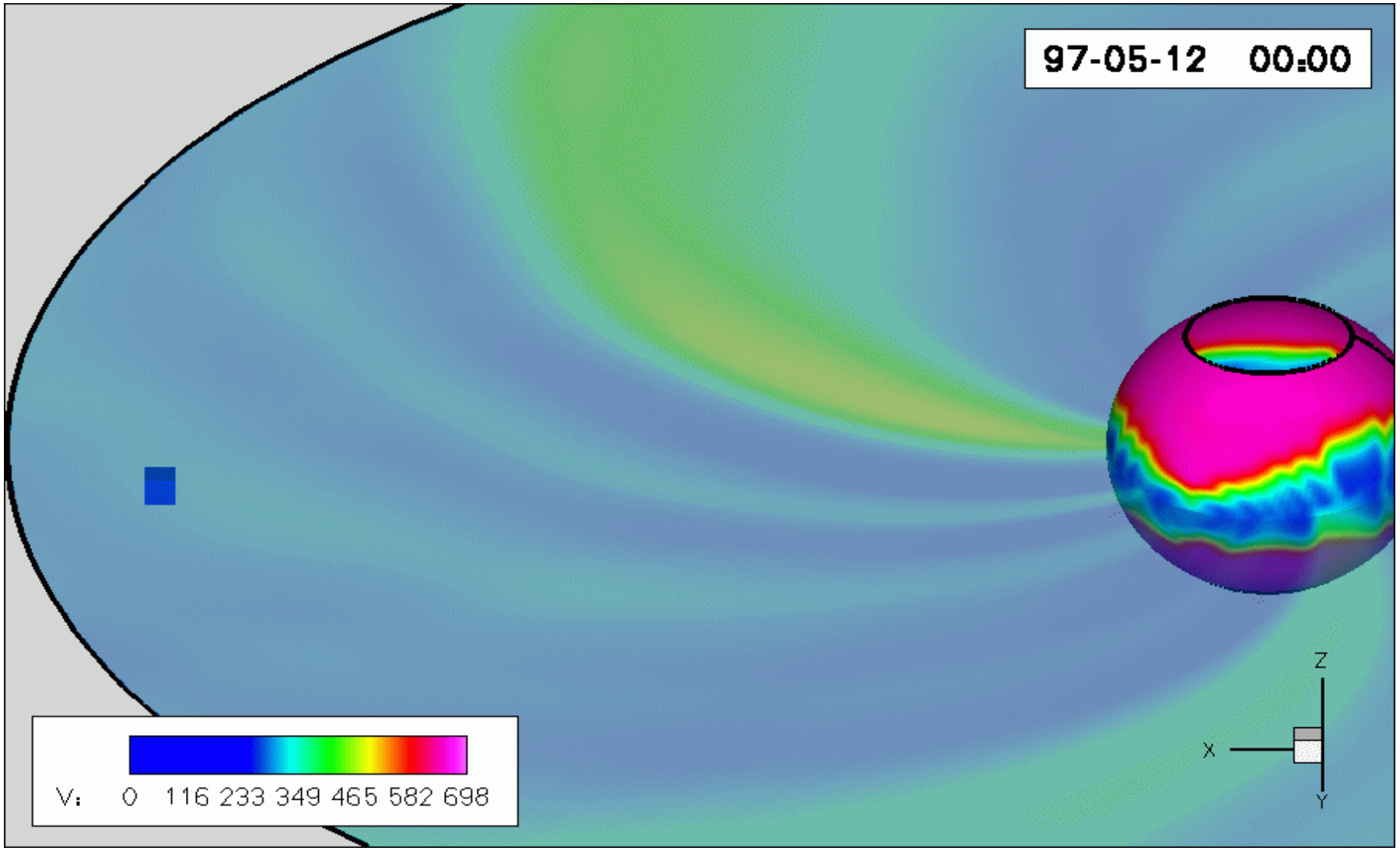
Geometrical and kinematical fitting:
provides latitude, longitude, angular width, and velocity (D. Odstrcil and X. Zhao figures, LASCO data)

May 12, 1997 Cone Model boundary conditions based on MAS model properties at 30 Rs (Cone Model runs in the ENLIL domain)



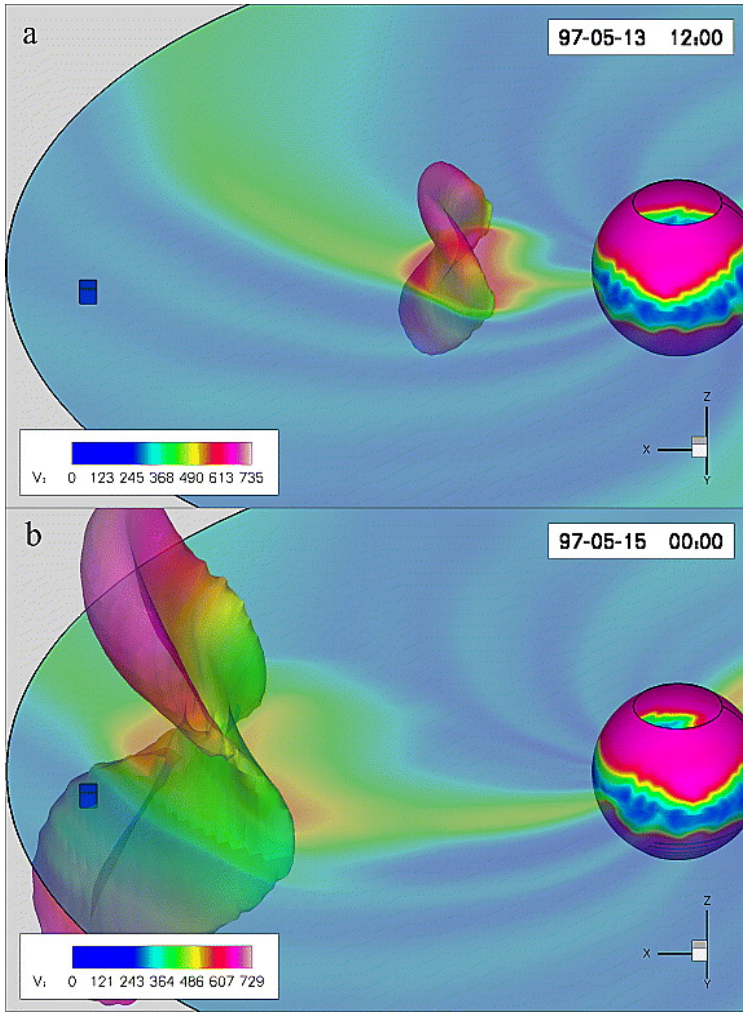
(D. Odstrcil image)

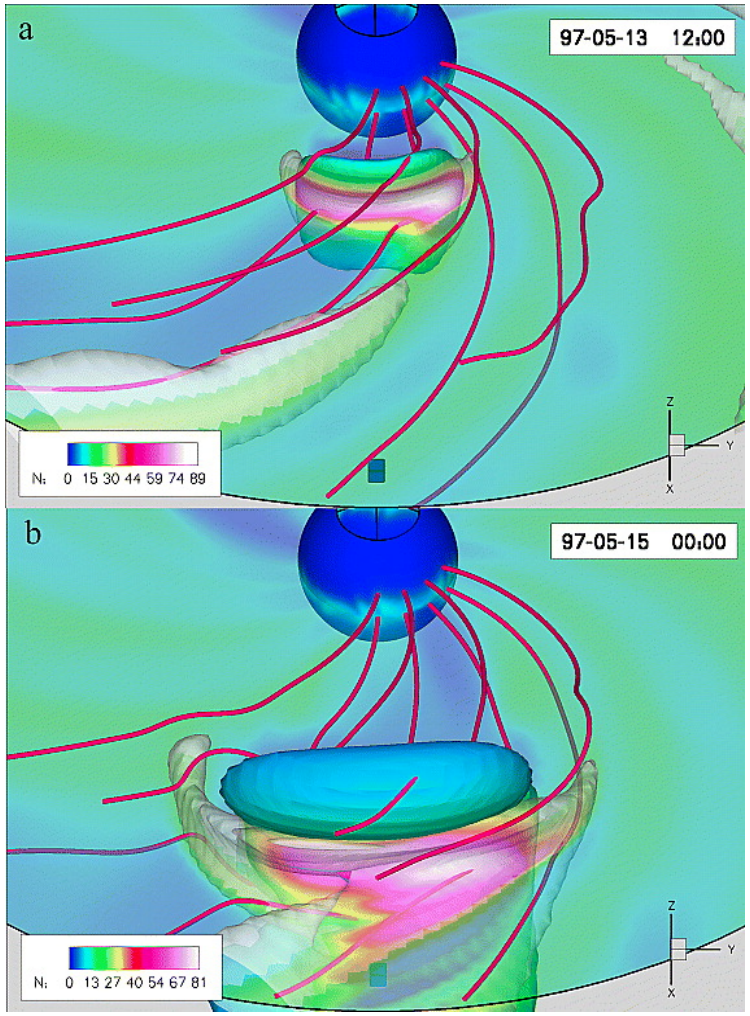
Cone Model, May 12, 1997 CME event…….



(D. Odstrcil image)

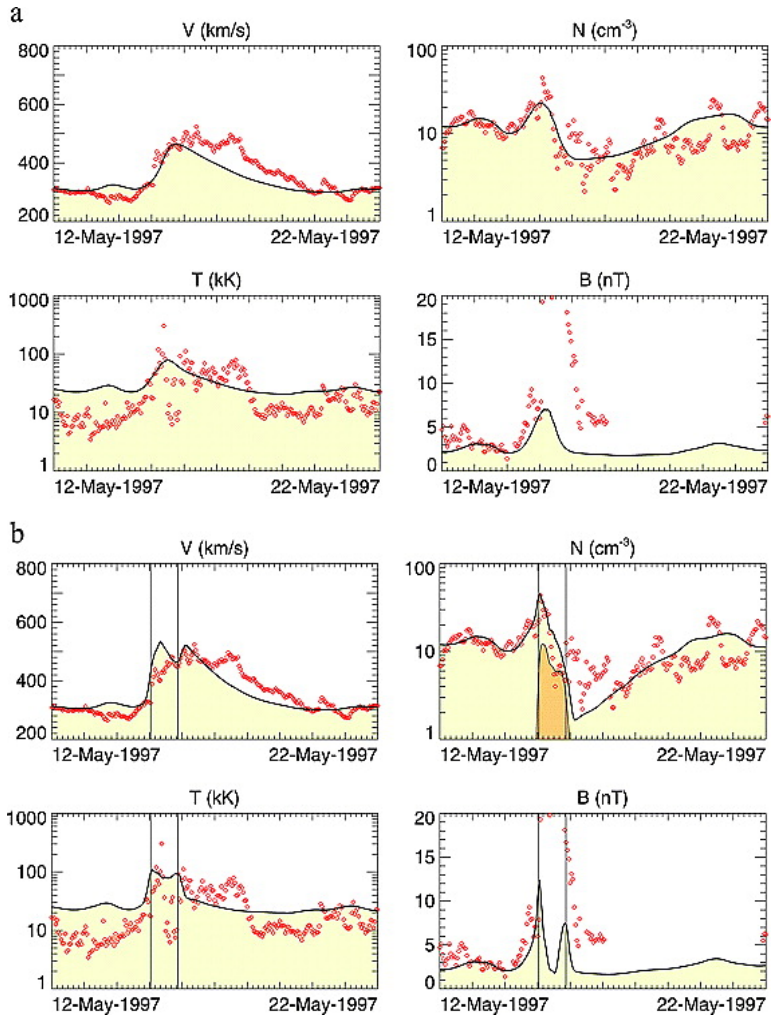
Cone Model details-density contours and interplanetary field lines





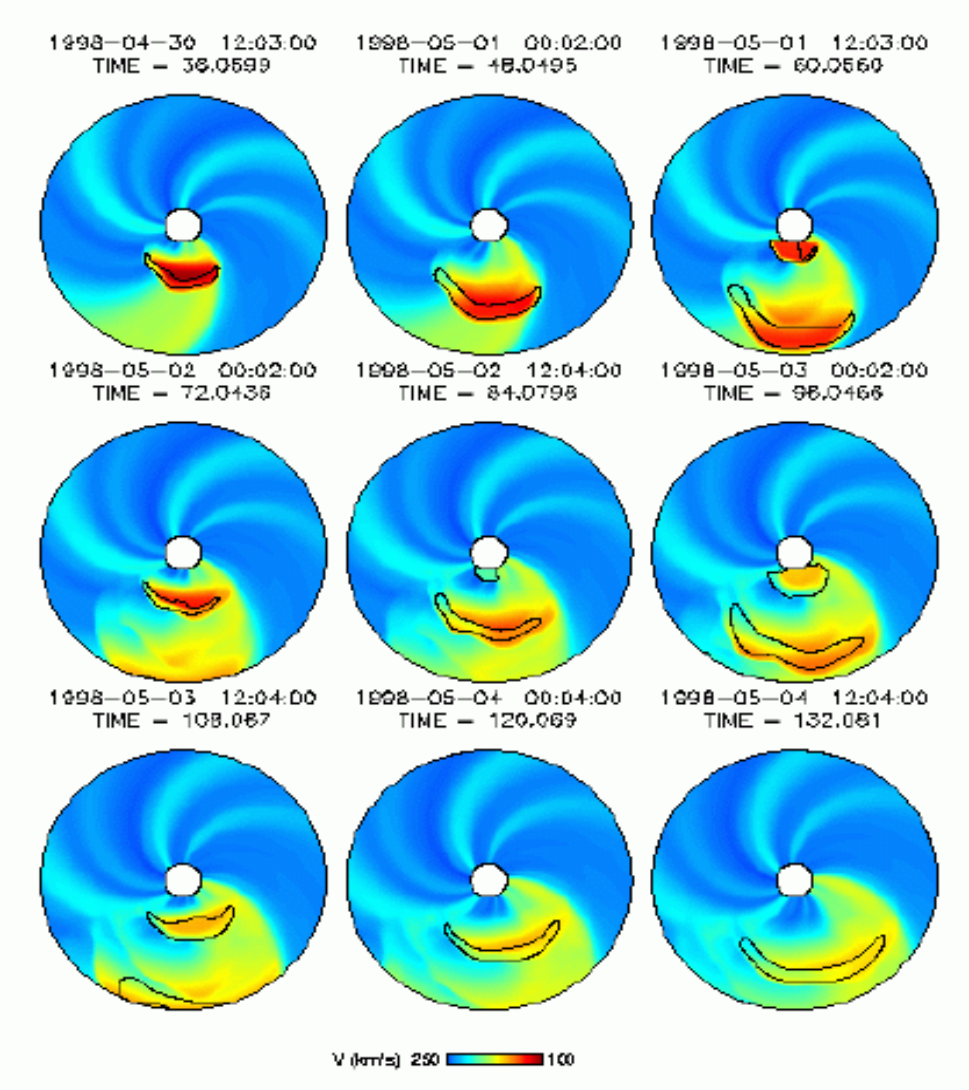
(D. Odstrcil image)

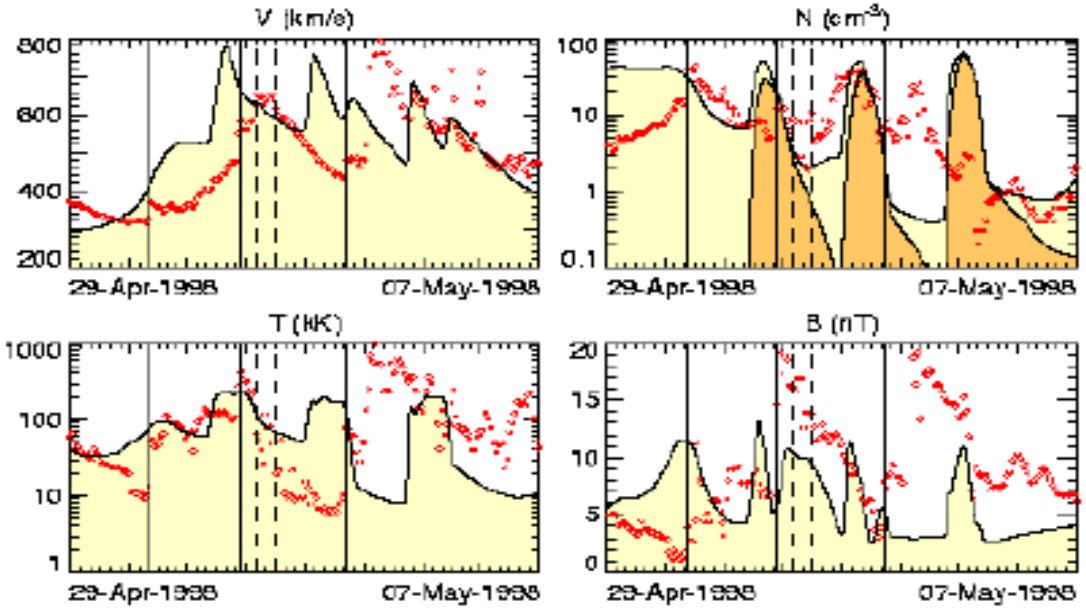
Simulated Cone Model in-situ parameters at 1 AU are compared to WIND observations on May 12-22, 1997……..



(D. Odstrcil image)

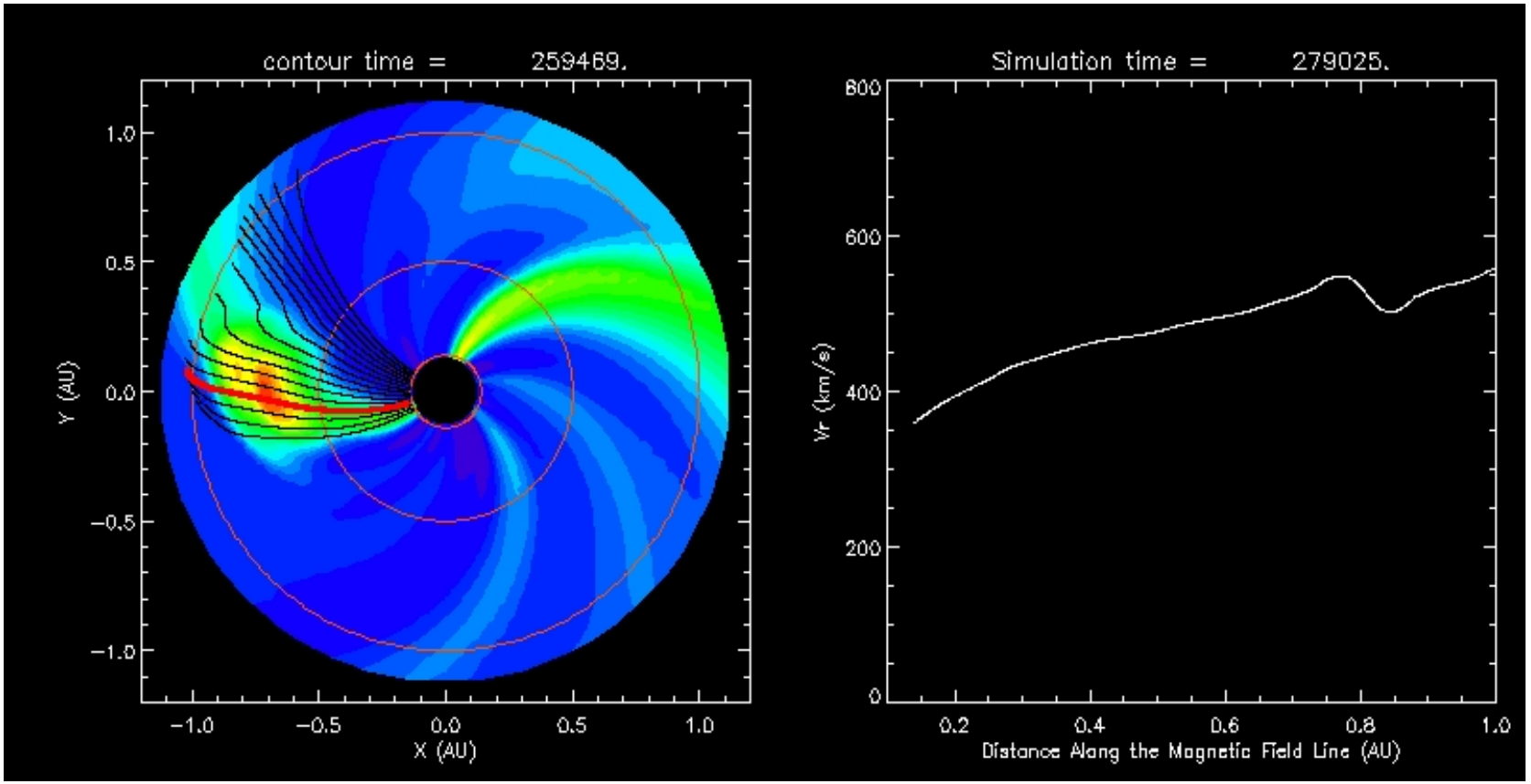
More complex cases of cone model runs are being examined (here, May, 1998 multiple CMEs), illustrating challenges ahead…….





(D. Odstrcil figure)

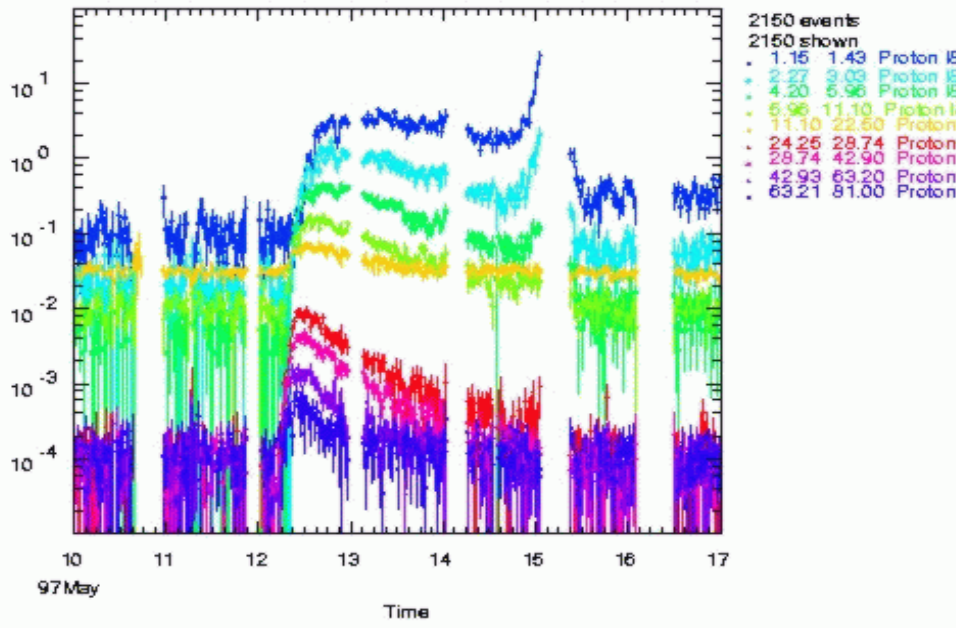
Snapshots of observer-connected MHD simulation field lines are saved to locate and characterize the shock source of SEPs



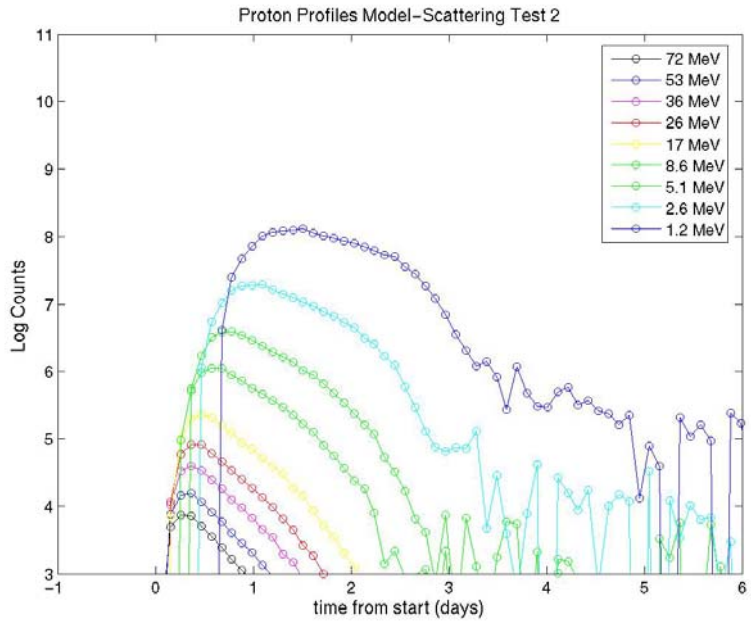
(Figure from S. Ledvina)

SEP 10-100 MeV proton time profiles are calculated in a post-process mode using saved MHD field lines and shock parameters

IMP-8



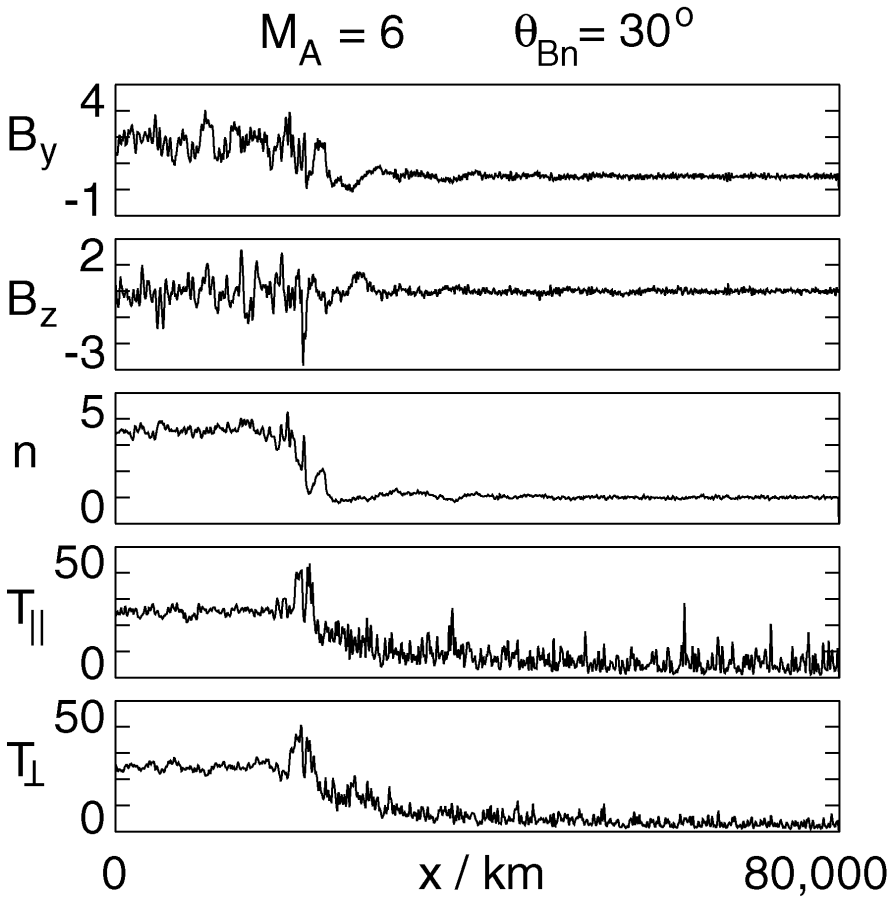
(data plot from A. Tylka)

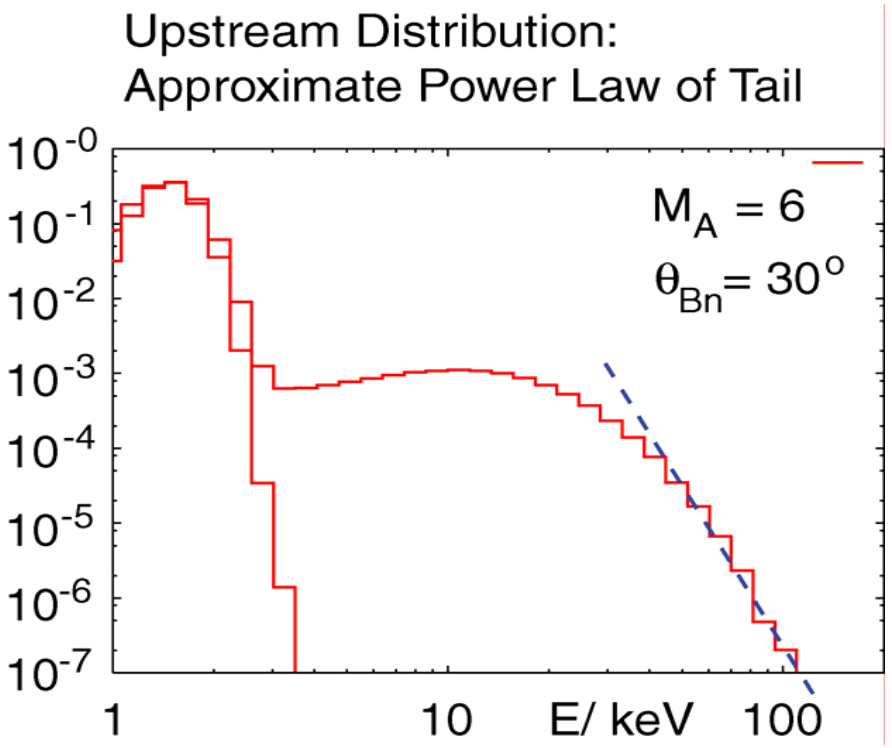


Sample calculated profile

Ion kinetic hybrid code results will eventually be used to create a physics-based shock source description……..

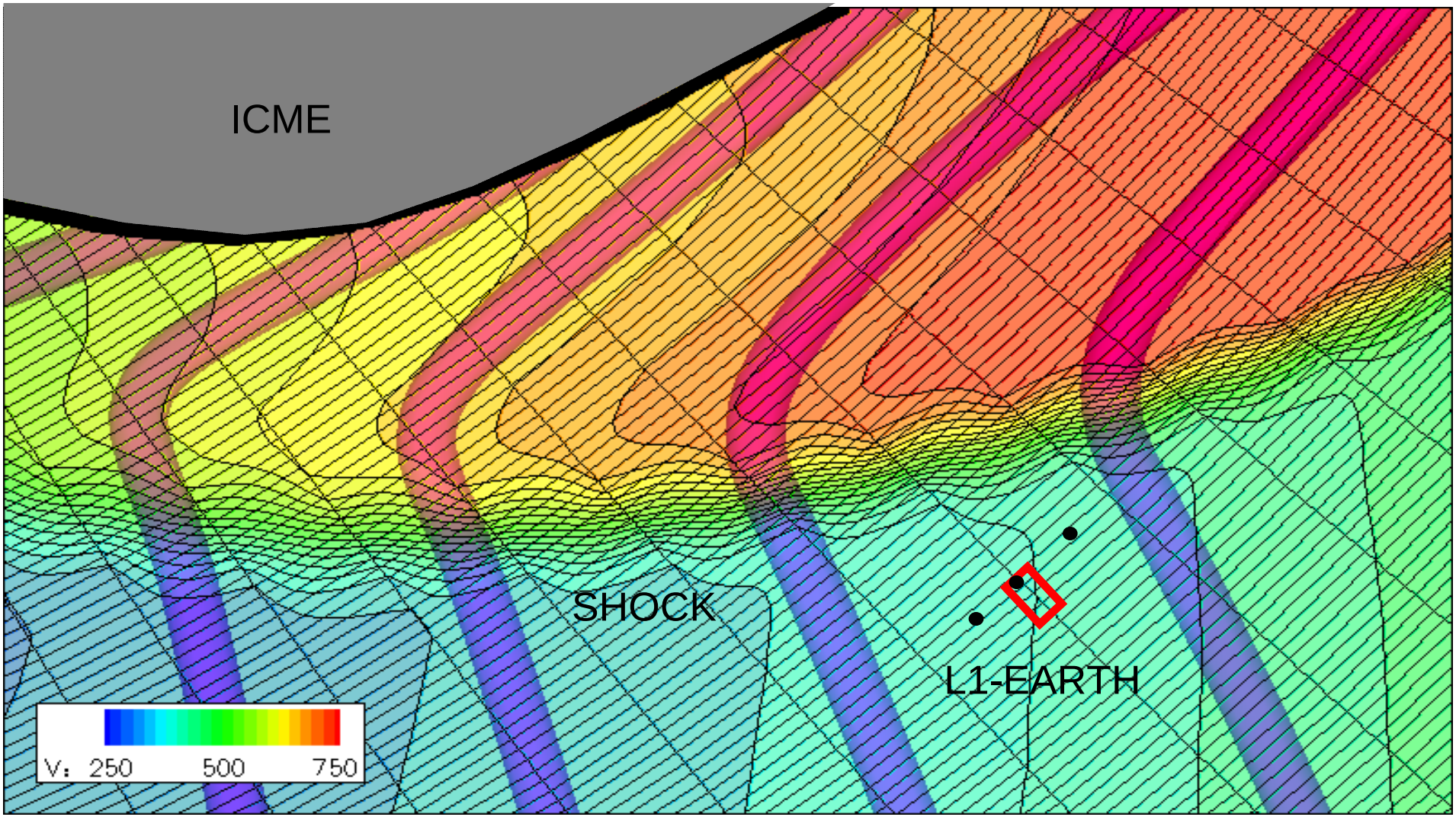
Ion Distributions: quasi-parallel case



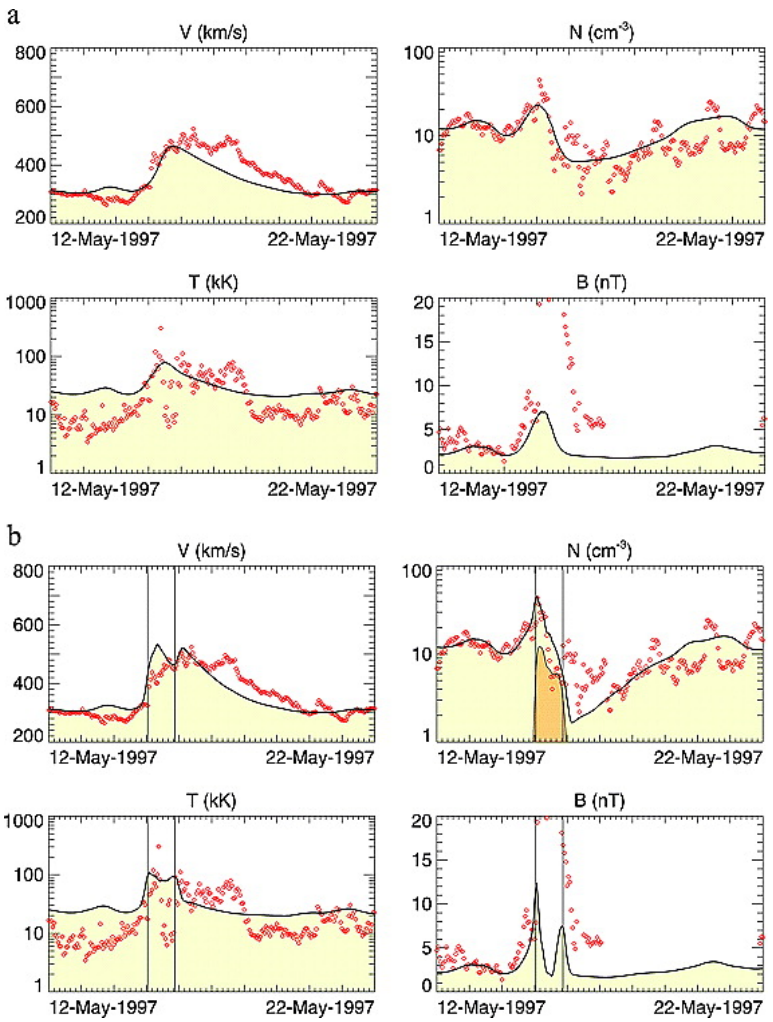


(figure from D. Krauss-Varban)

Geospace coupling is currently single ENLIL grid point-based

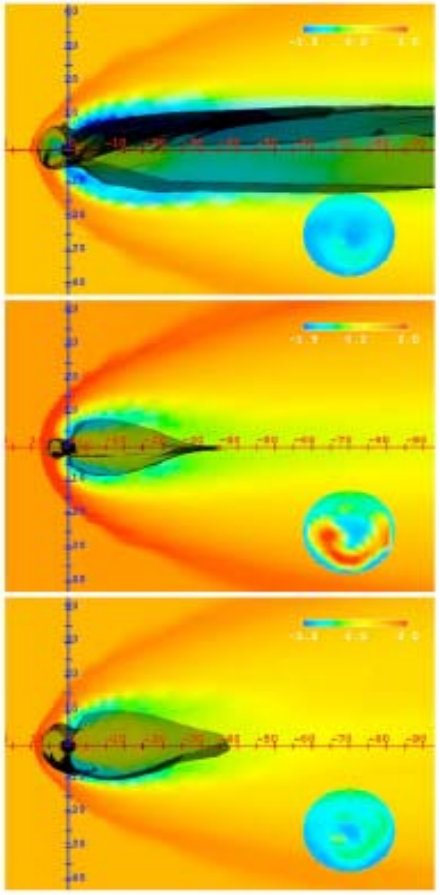


Simulated Solar Wind Parameters at L1



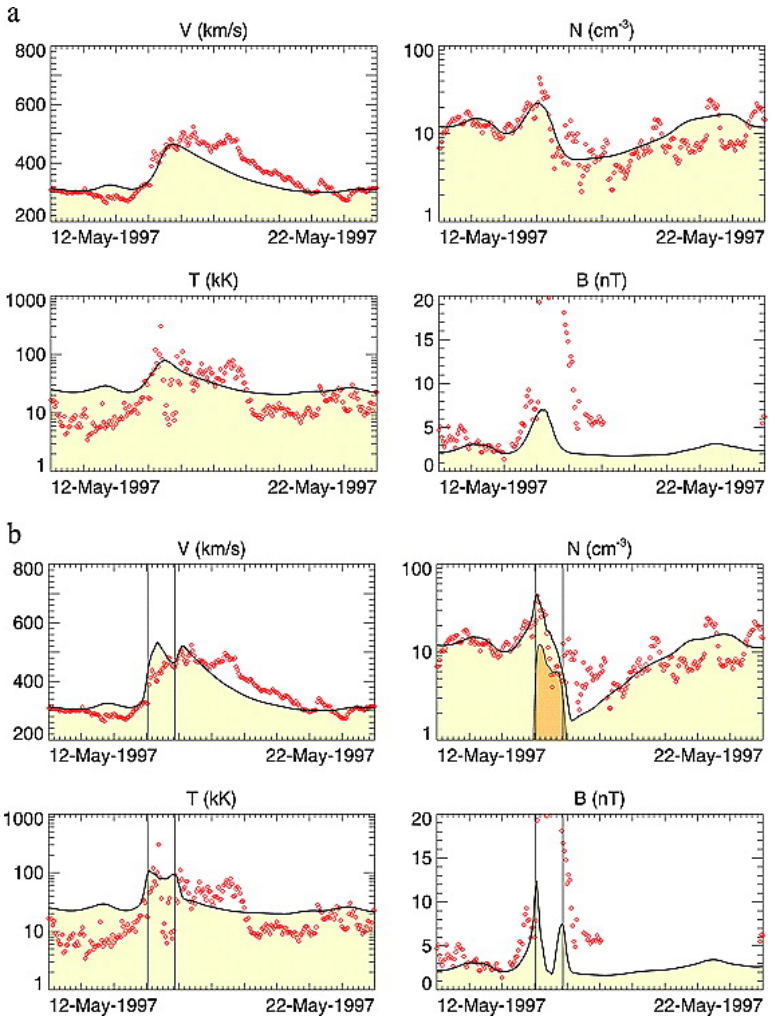
From D. Odstrcil

Result in driven CISM geospace model responses including high latitude energy input (inset).



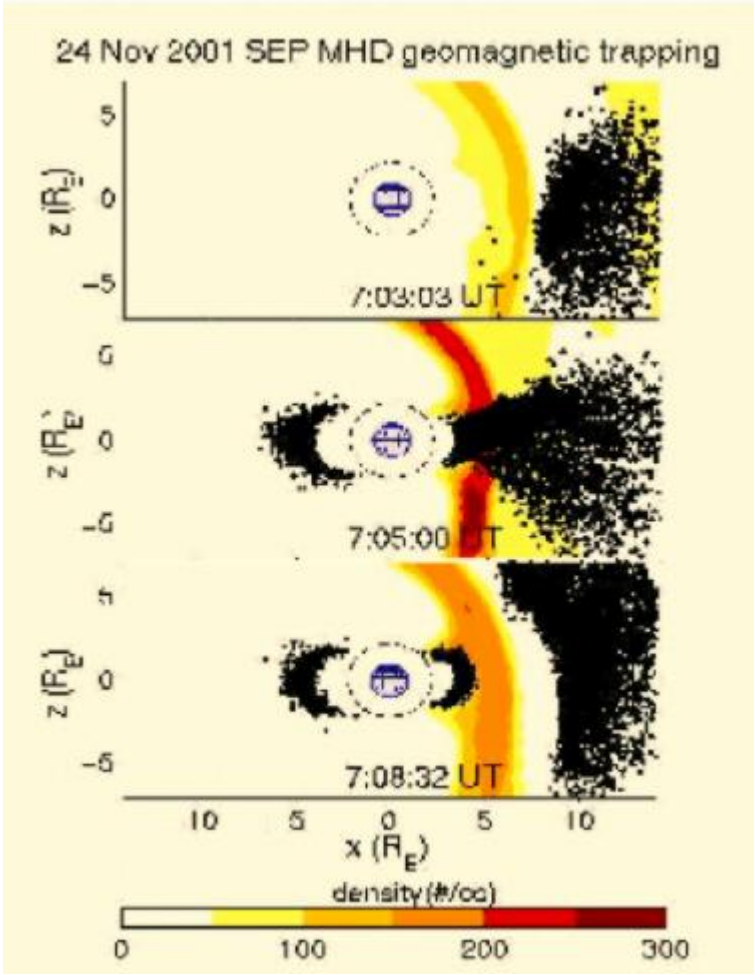
From M. Wiltberger

Simulated Solar Wind Parameters at L1



From D. Odstrcil

…and SEP access to the magnetosphere and polar cap



From M. Hudson, B. Kress

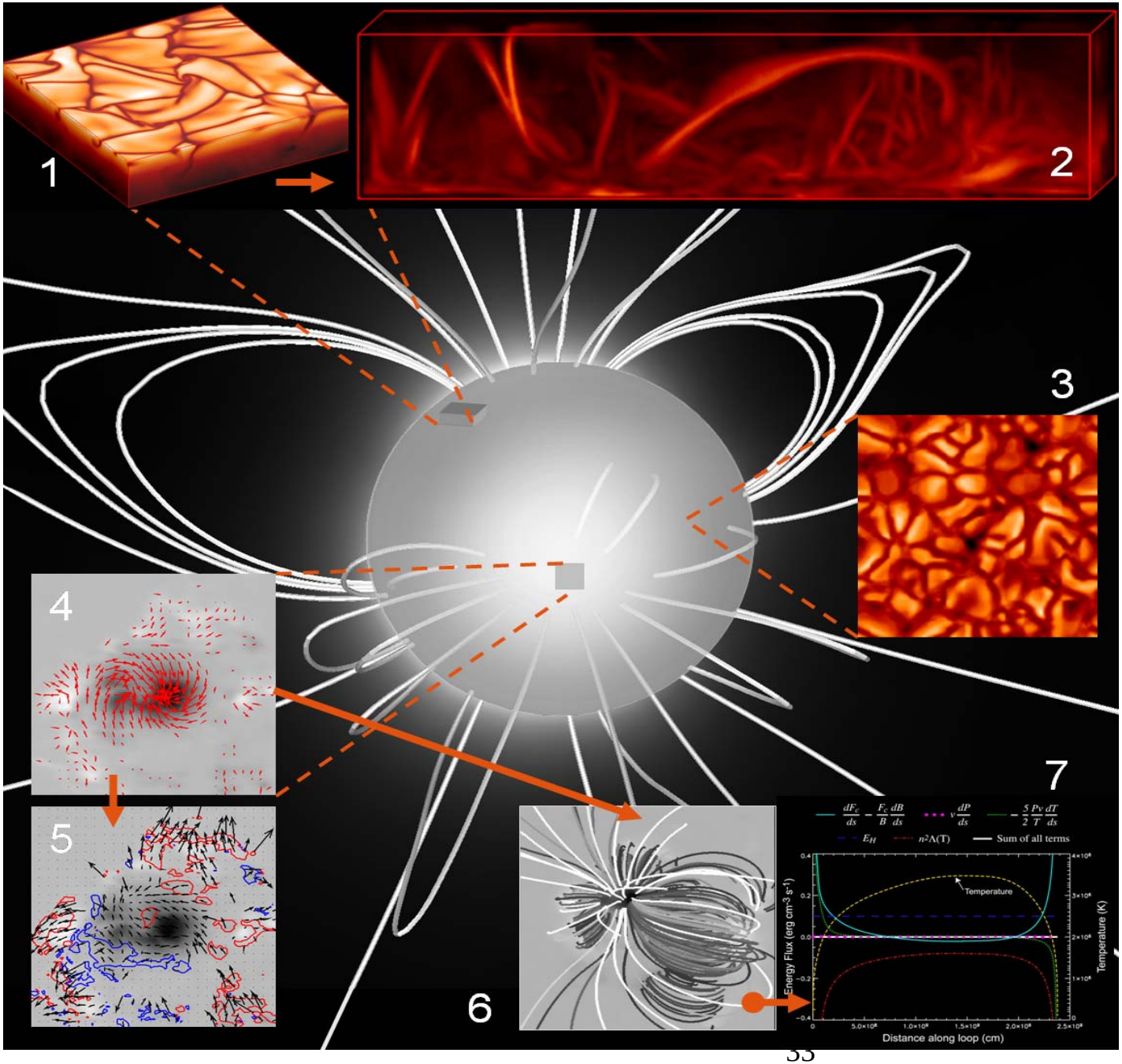
event simulation plans

-> The Cone Model will be developed into a CORHEL-like general use code for “cone modeled” transients and validated, with a post-process SEP model

-> The May 12, 1997 CME realistic initiation case will be completed (solar wind added, propagation to Earth, SEP event model) and validated

-> Experiments with other initiation schemes and case studies are underway and will follow the May ’97 event path

-> CISM collaborations are encouraged!



CISM has benefited from the Solar MURI Program Center at UCB -e.g.the approach to observation-driven eruptions through Local Correlation Tracking

Collage of Solar MURI results, From Bill Abbett

Luhmann