Chromospheric and Coronal Magnetic Fields

Thought it would be easy - just comment on good talks

Wow !

So many interesting advances !

Such an exciting set of talks !

European solar physics -- excellent shape

What key points learnt ?

STRUCTURE of Magnetic Field

1. Photosphere
2. Chromosphere
3. Corona - observations, theory

DYNAMICS

4. Coronal Heating
5. Prominences
6. Emerging Flux
7. Eruptive Instability
8. Waves

Life was simple

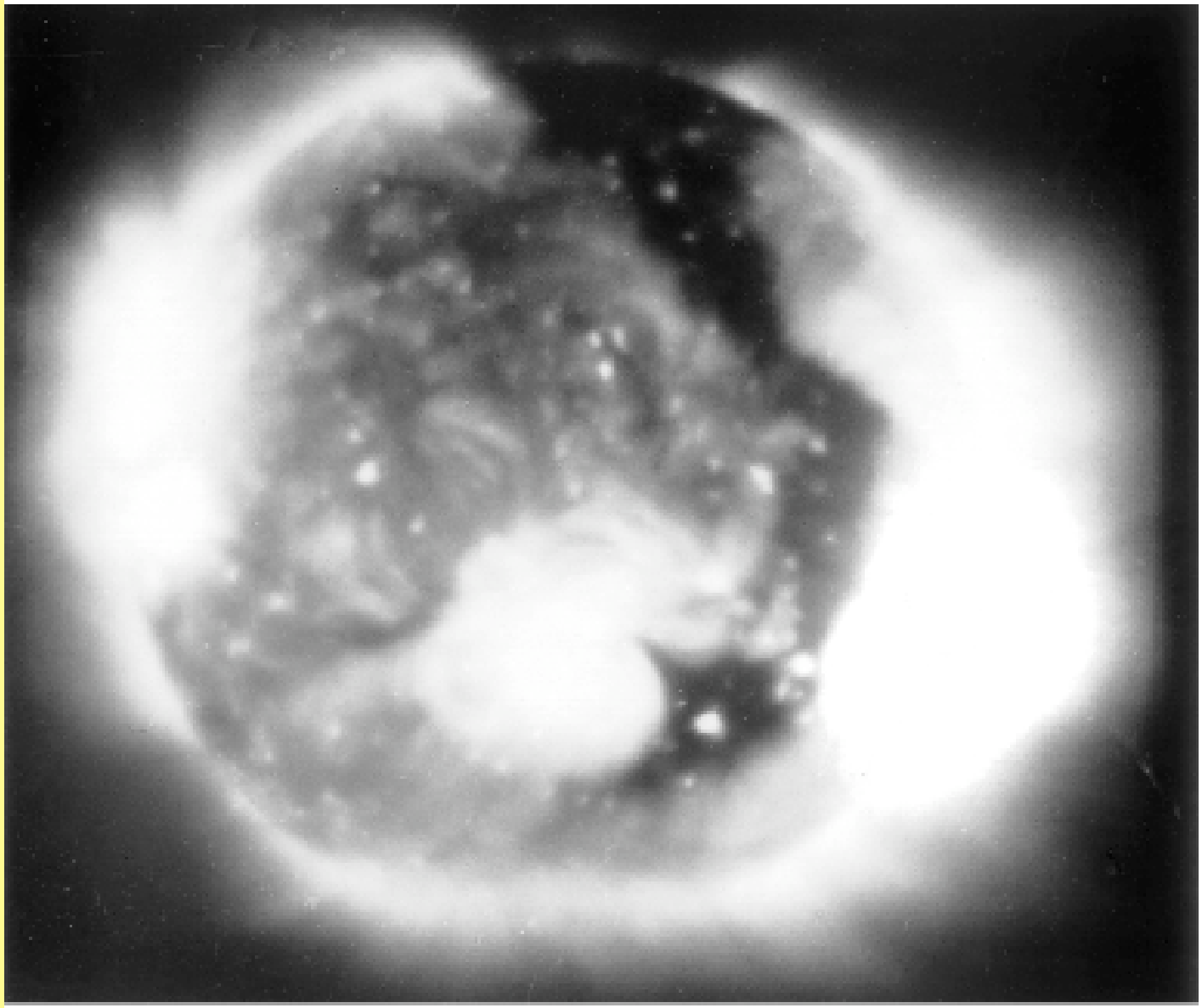
When we were young / naive

When **static**,

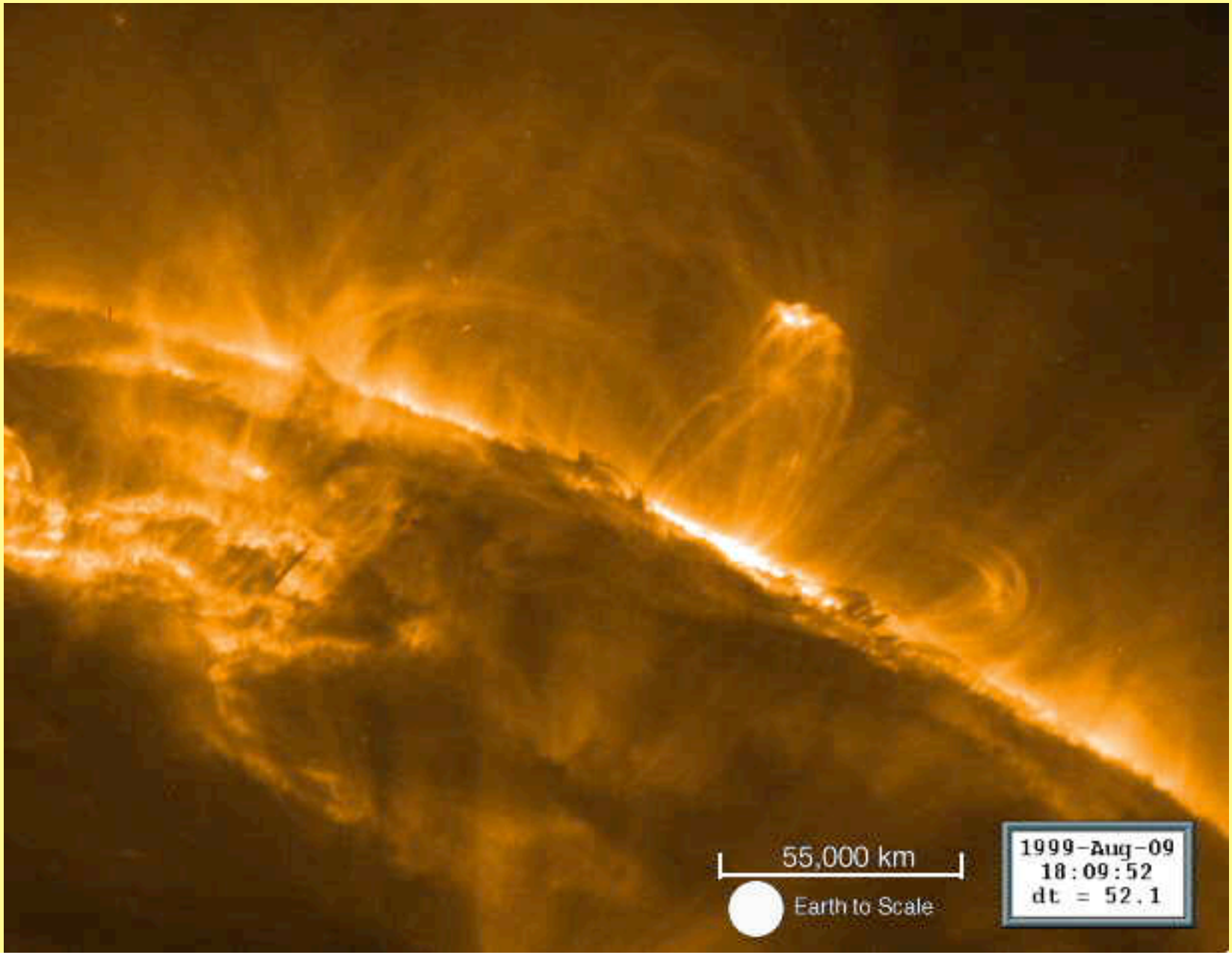
chrom/tr/corona

-spher^{y} sym^{c}(r)

When **B=0**



Now **loops**, **B** everywhere, **Dynamic**

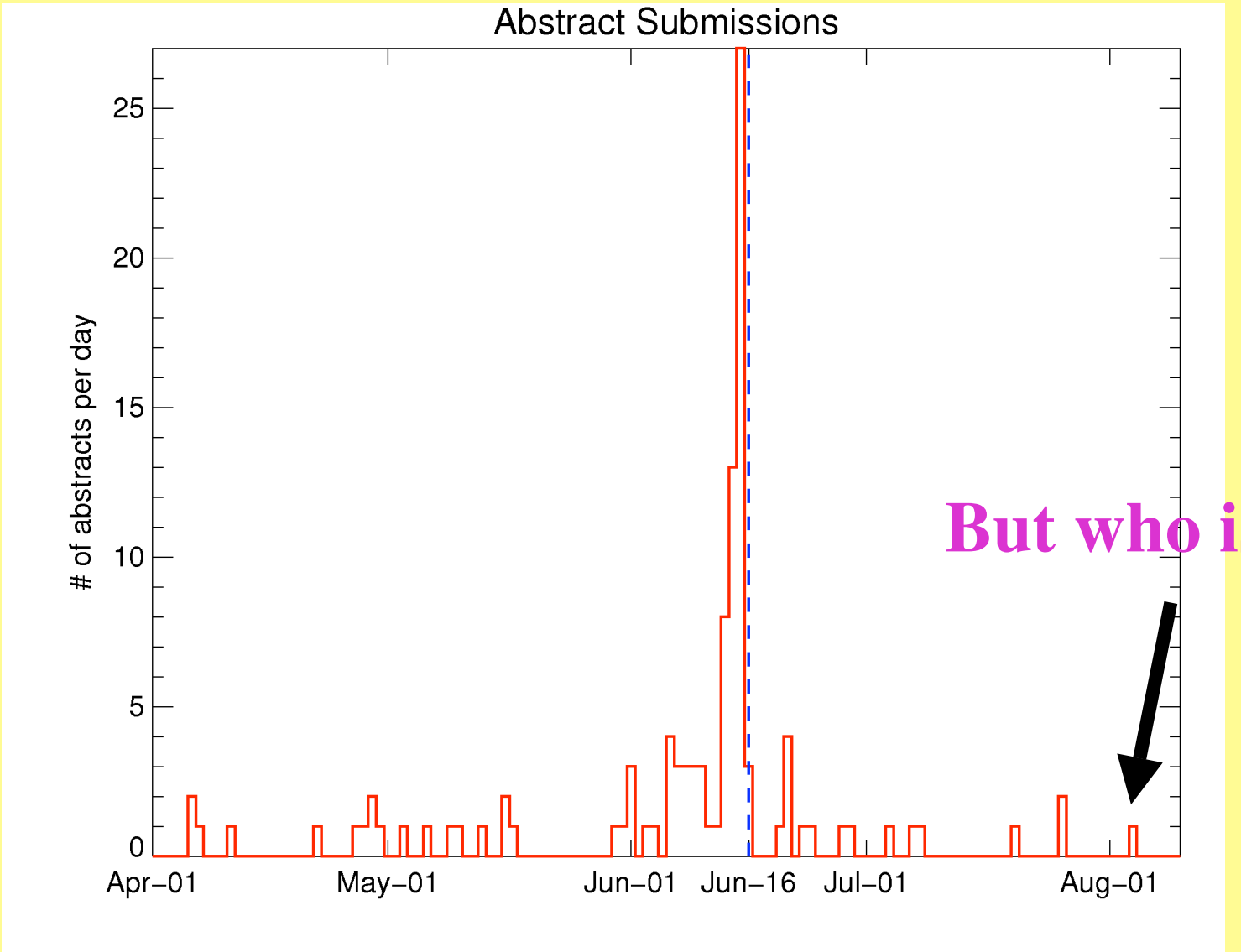


TEST - -

Who said " This is certainly the lousiest talk" ?

Distribution of submission of abstracts as function of time

Guess -- when was the submission date ?

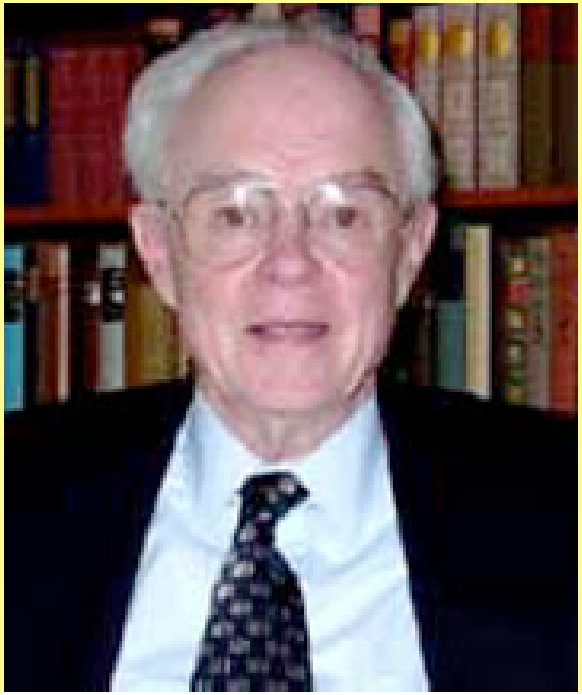


But who is this ?

Who said ?

"If you've heard this before, you can doze for a few minutes"

"There are also problems with dynamo theory - if you have another hour …."



Who said ?

"The Sun with no magnetic field would be a star with no spirit" ?

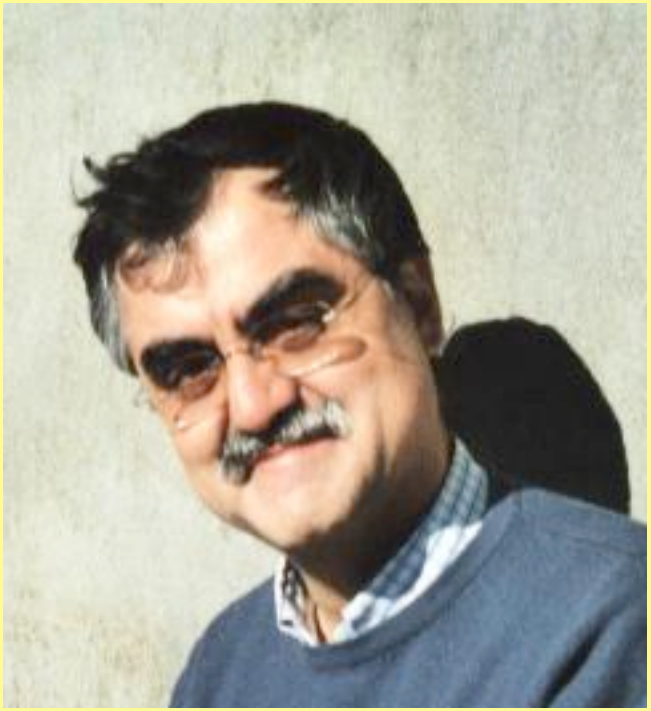
Nour-Edine

Who said ?

"The good news .., The very good news …,
Is there any bad news? "

"You build a polarimeter, put it into space - it'll take you 10 years …. but then I will have solved the problem !!" ?

Javier

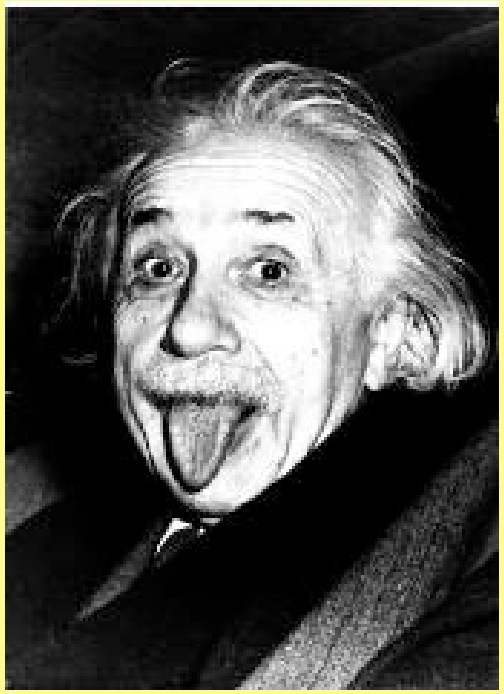


Who said ?

"Most of us come from flatland"

"God blesses radio astronomers
(the anthroporadiomorphic principle)" ?

Stephen



Who said ?

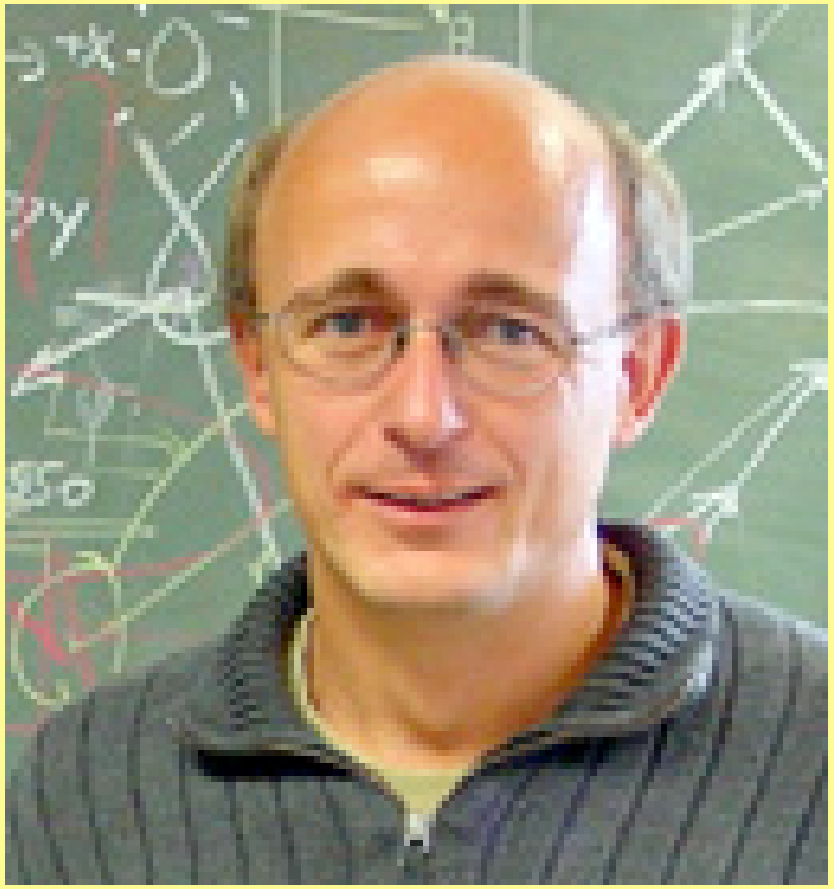
“I know everything about bald patches”

Thomas

Who said ?

"The canopy is like a wineglass"

Andreas



Who said ?

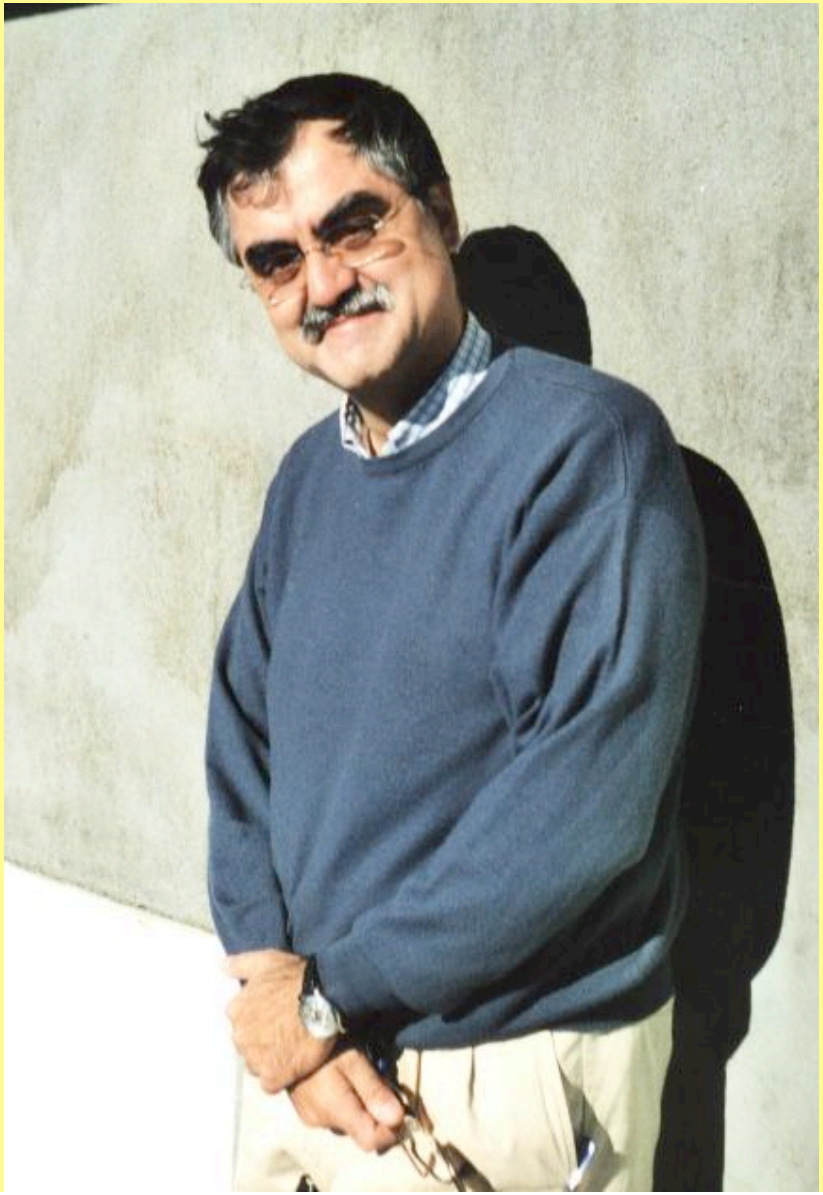
“In a dextral filament
you are on a highway
& going to the exit”

Brigitte

Who said ?

“You can have only 1 final question - I am hungry”

Javier



Who said ?

"Our talks in this session are having trouble with the referees"

"I'm not so sure I like kink instability"

Spiro

Who said ?

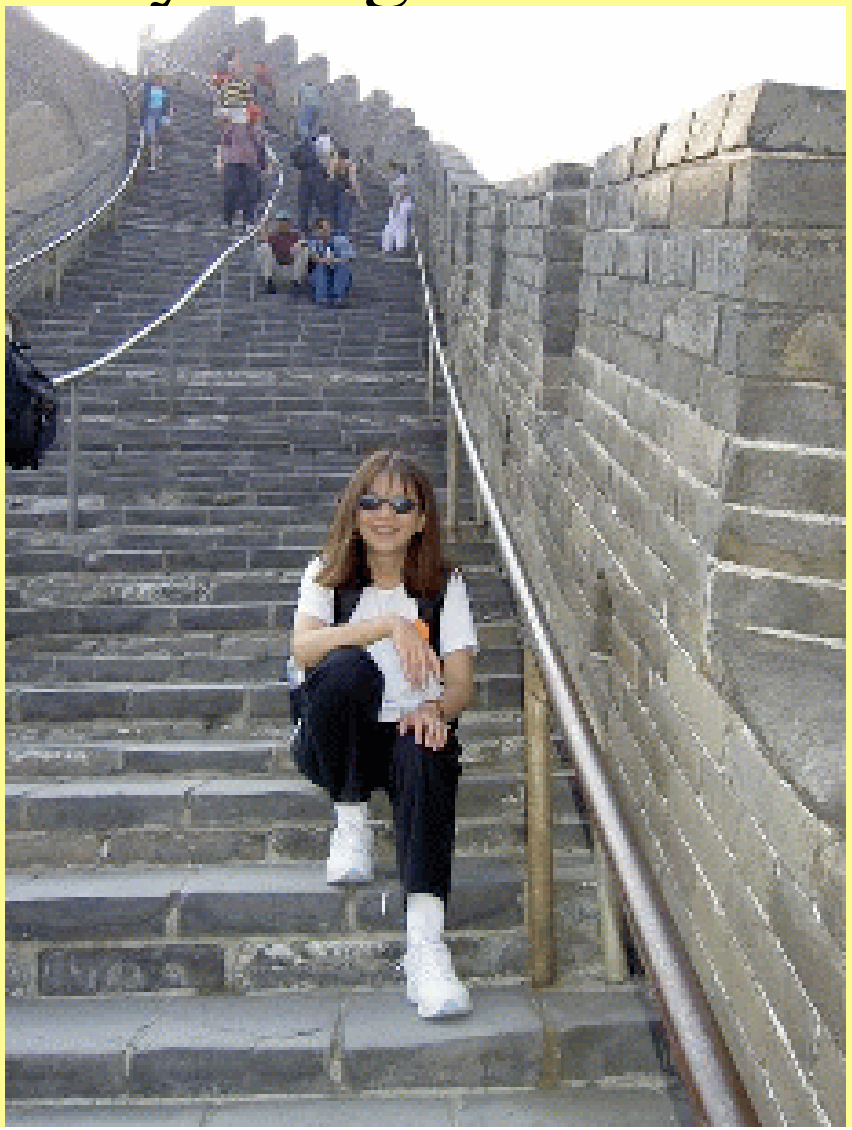
“I am agreeing with Spiro - which is disheartening”

John

Who likes ?

“chewy nougat”

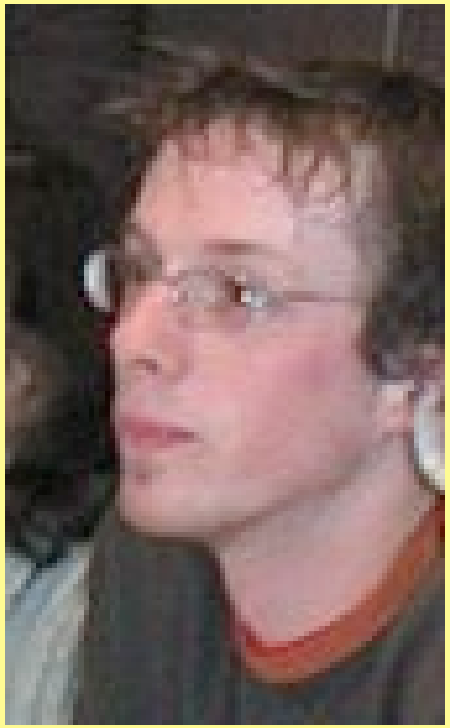
Yuhang



Who said ?

“The black stuff is just chromospheric junk”

Jorrit



Who could talk or see but not do both ?

Cristina

Who said ?

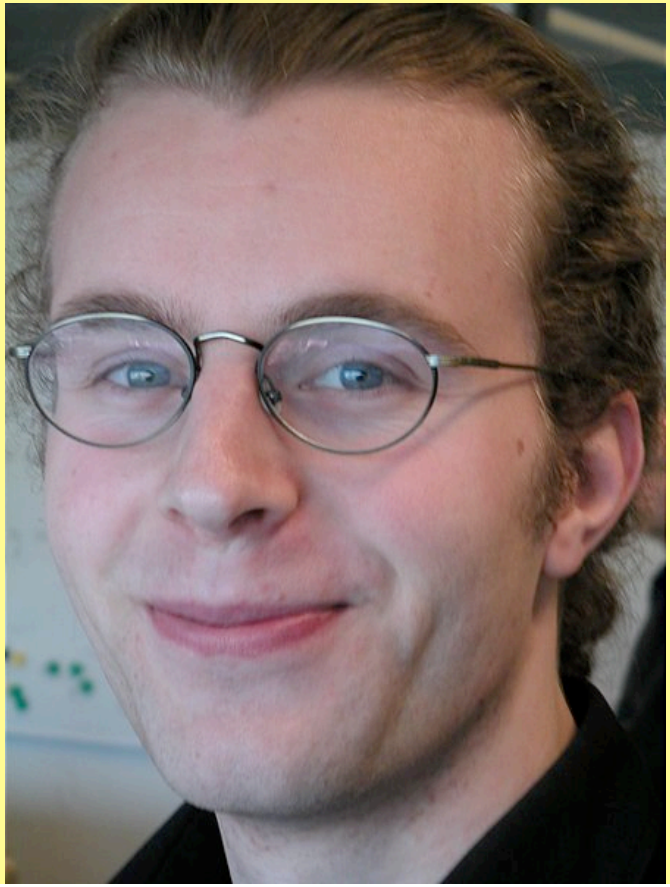
“It may be a good idea for me to speak, so that the audience can cool down after Spiro” ?

Ineke

Who said ?

“This nice formula didn’t survive translation from laptop to computer”

Alfred



Who said ?

“These equations are not meant to destroy your attention”

Joerg

Who sent her family to China for this meeting ?

Davina

Who said ?

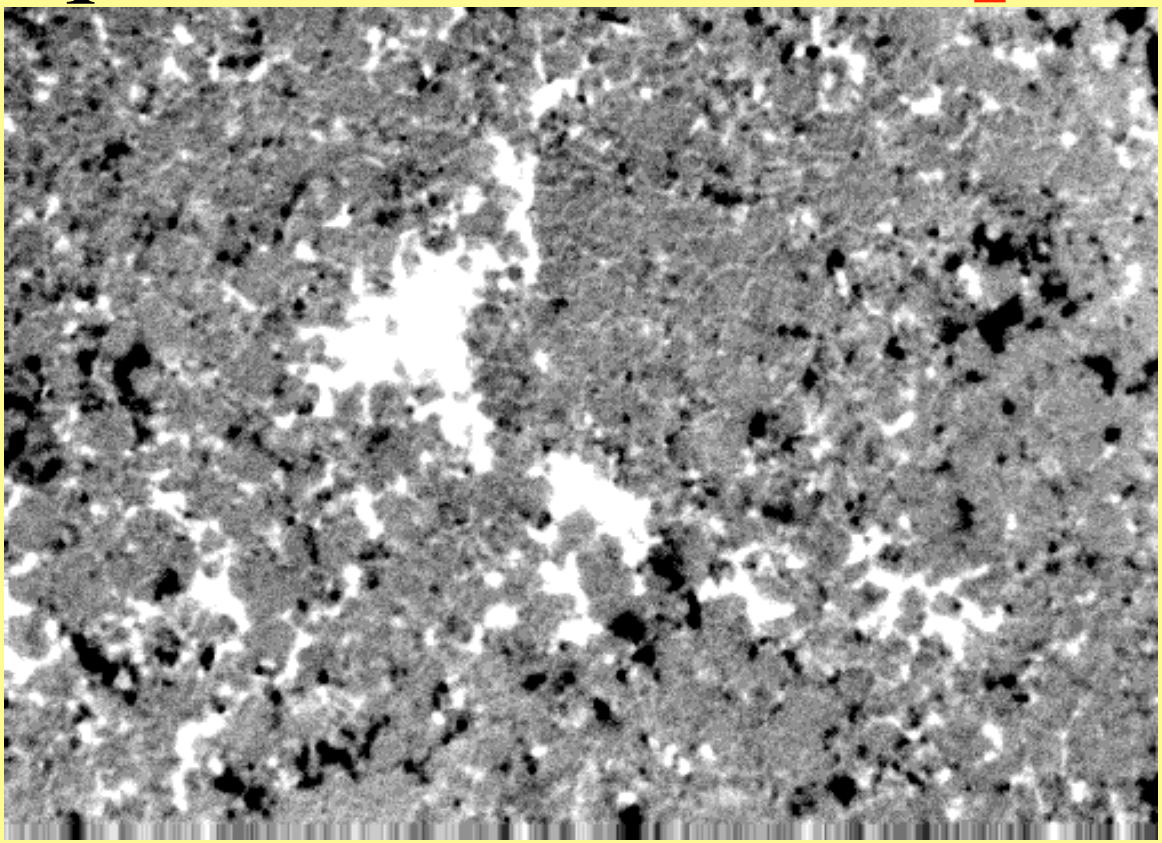
“You may realise the Sun is not an infinite plane”

Sami

1. Structure of Photospheric B

Hector Navarro The quiet Sun is ***not-so-quiet***

[Arturo Lopez]

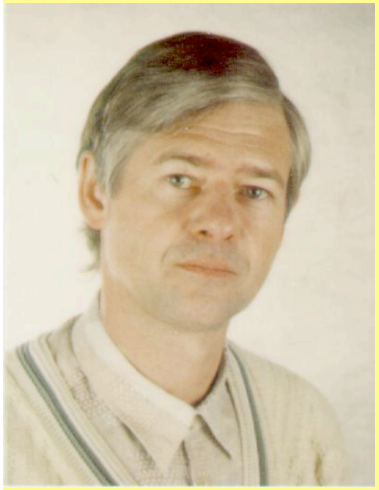


– Ratio flux in network/cell ?

--What is intrinsic field strength ? PDF of flux in pixel ?

-- Origin of these fields?

Horst Balthasar

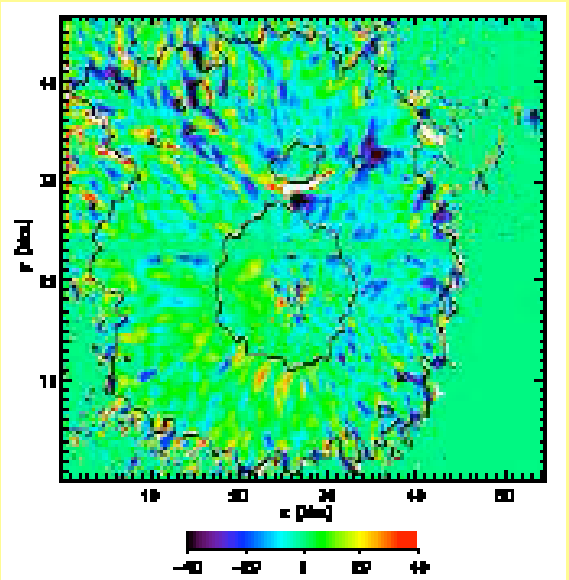


Vertical current in sunspots:

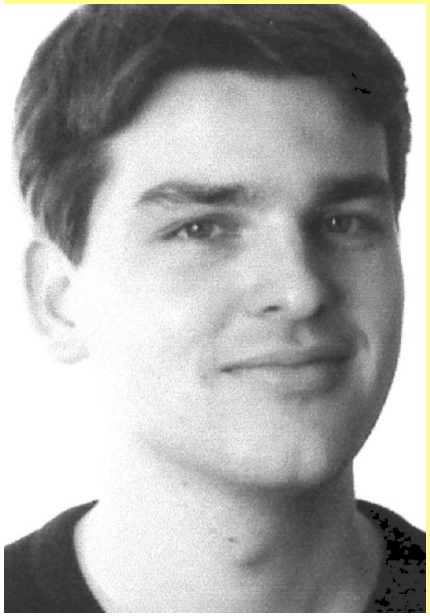
$\pm$ 100 mA/m^2

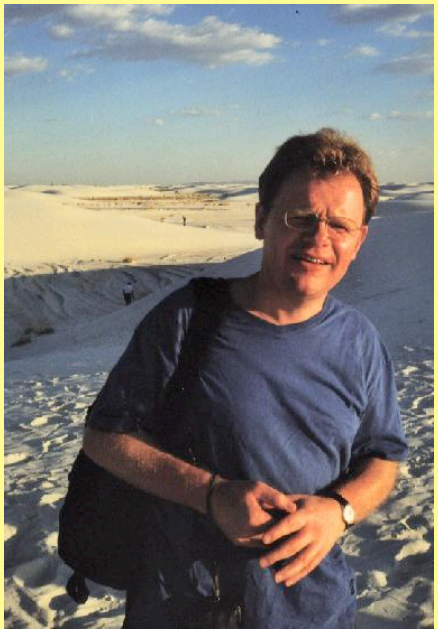
$= j / B$ varies by factor 100

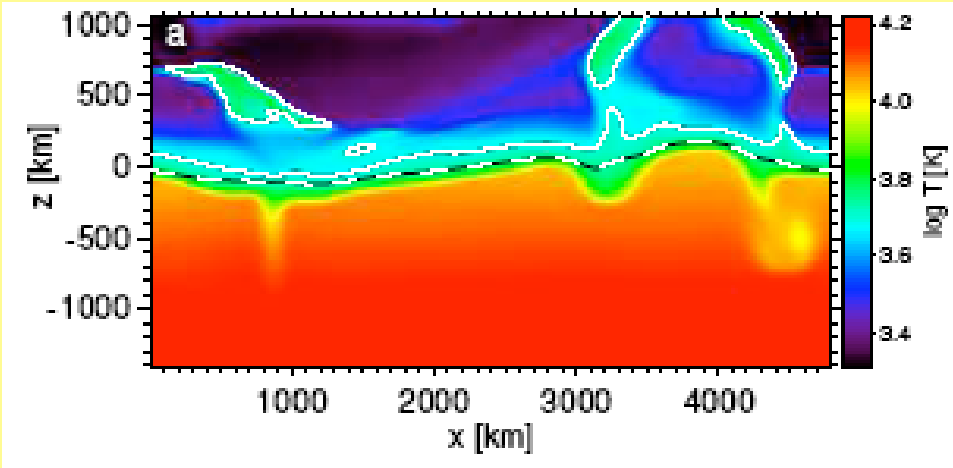
-- so not **linear** fff



Sven Wedemeyer-Bohm, Oskar Steiner





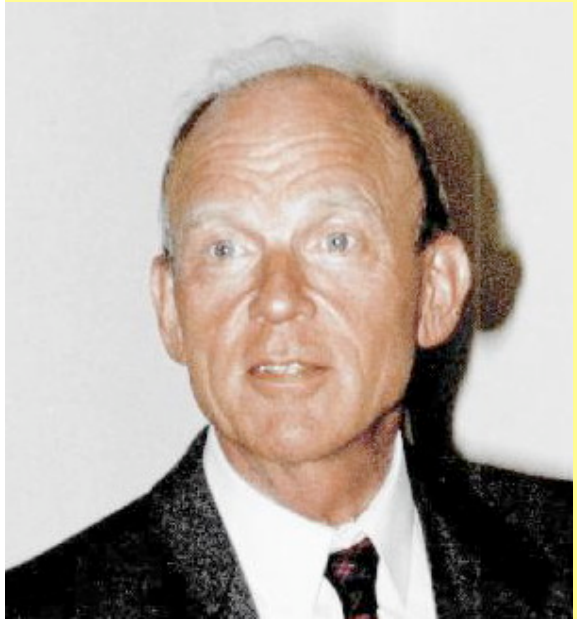


Simulations of CO & **B** in quiet Sun w. radiative MHD code --> **chromo. very dynamic** with filaments

Jorrit Leenarts

BP's in H_{alpha} wing coincide w intergranular B of 1 kG

Eberhard Wiehr

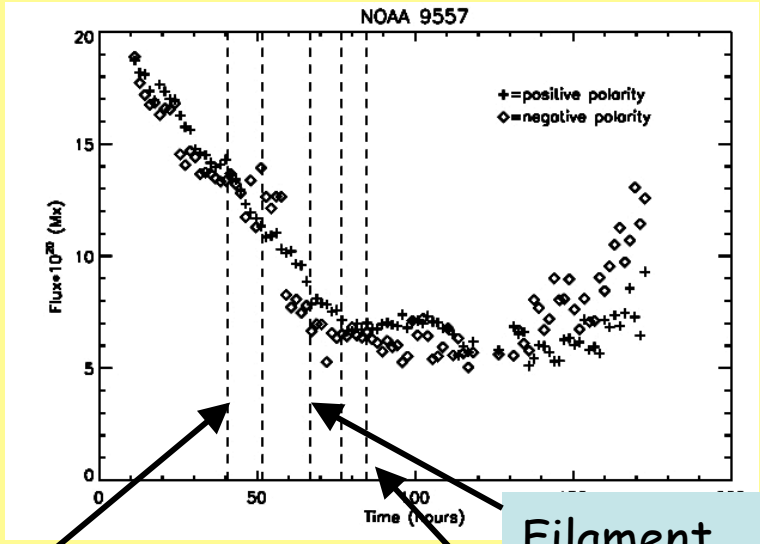


Gap in flux between G-band bright points & smallest dark pores

? Simultaneous magnetograms

Valentin Martinez

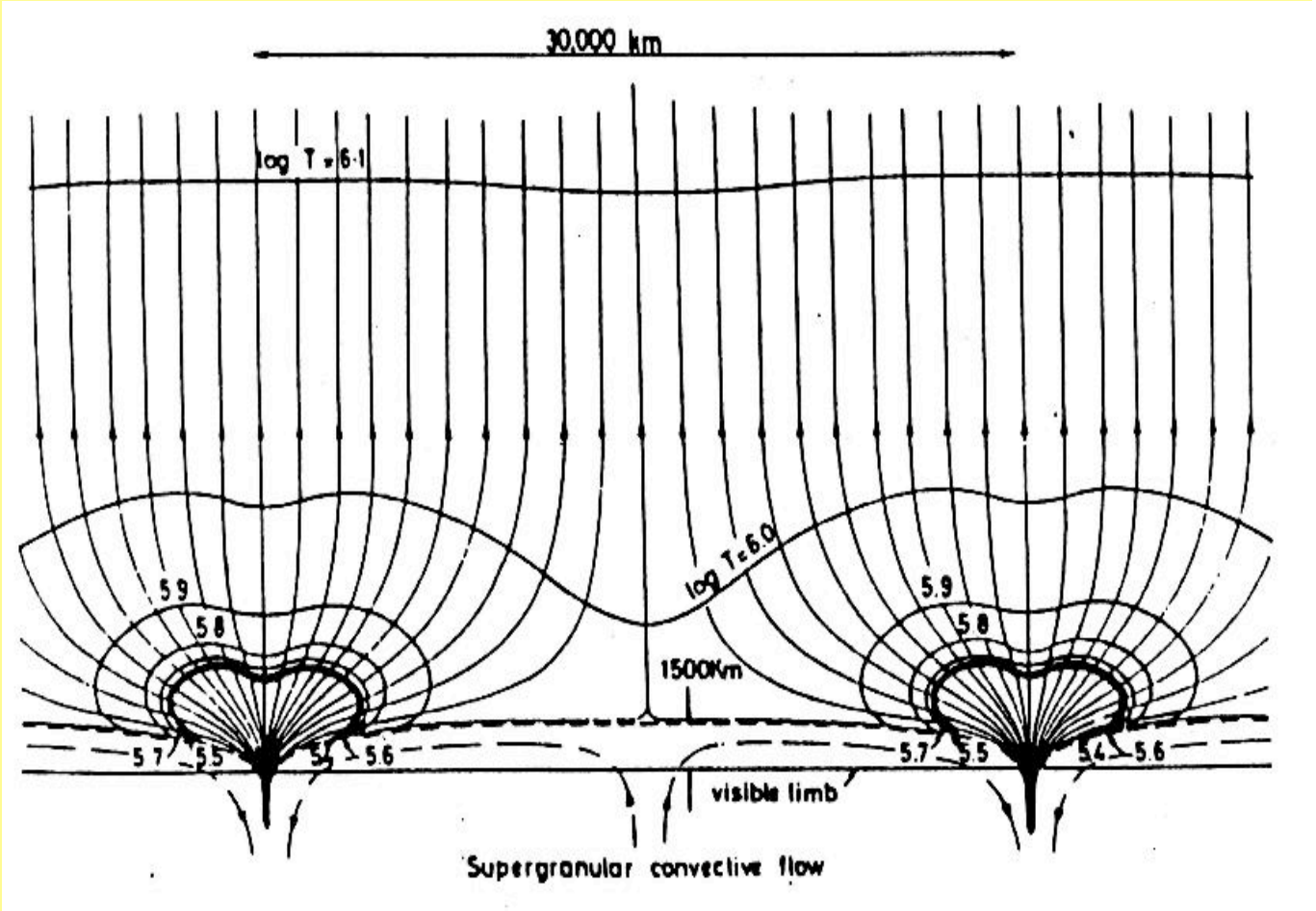
Active regions lose 70% flux by cancellation,
30% can diffuse towards poles



1.5 Relation Photosphere-Chromosphere

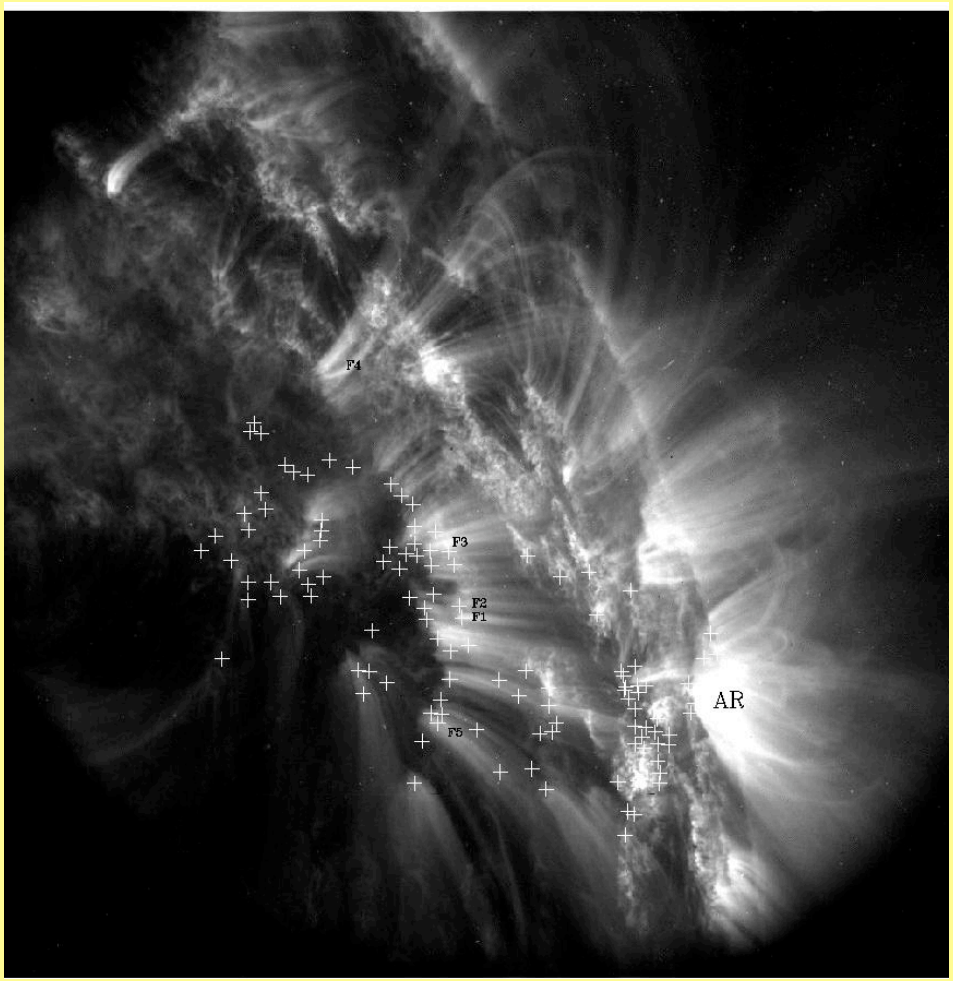
Mei Zhang - **Traditional canopy model**

too simple



magnetic element in chromosphere not >> photosphere !

Trace loops ?



Confinement not a problem

-- ambient B

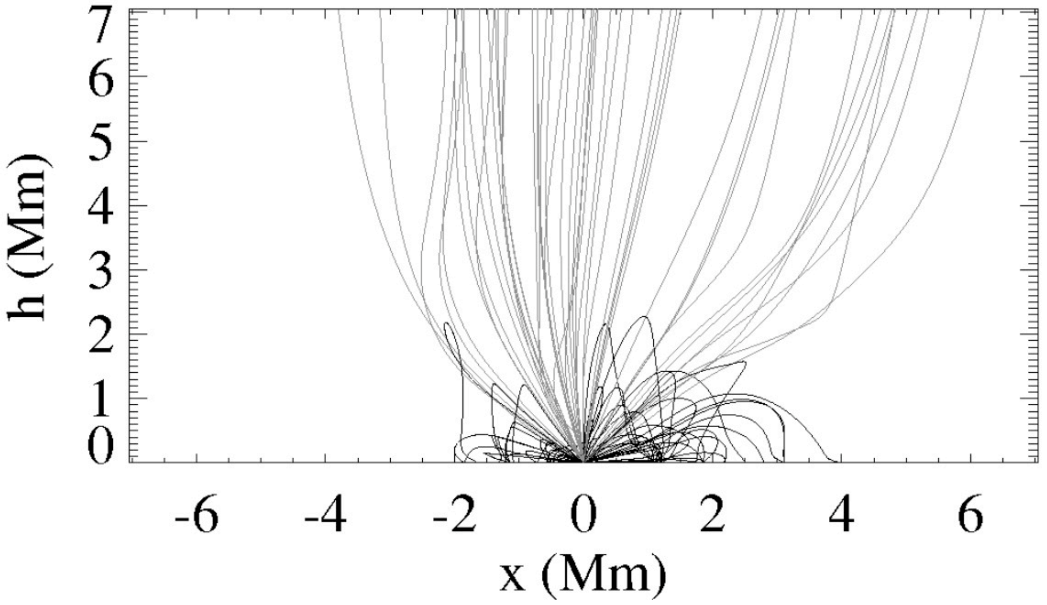
But puzzled about
why Trace loops vertical
& constant cross section ???

One possibility --
lie on separatrix surface

Karel Schrijver - review of Magnetic Carpet

- Topologically very complex - reconnects every few minutes.
- Most of Trace heating is in small-scale flux in network.
- Corona over quiet Sun is not ff - beta order 1

- Much more flux in cell (intranetwork field) !
- Canopy - only 30 - 70% of open field ends in network.
- Intranetwork field generated by small-scale dynamo --> heats chromosphere



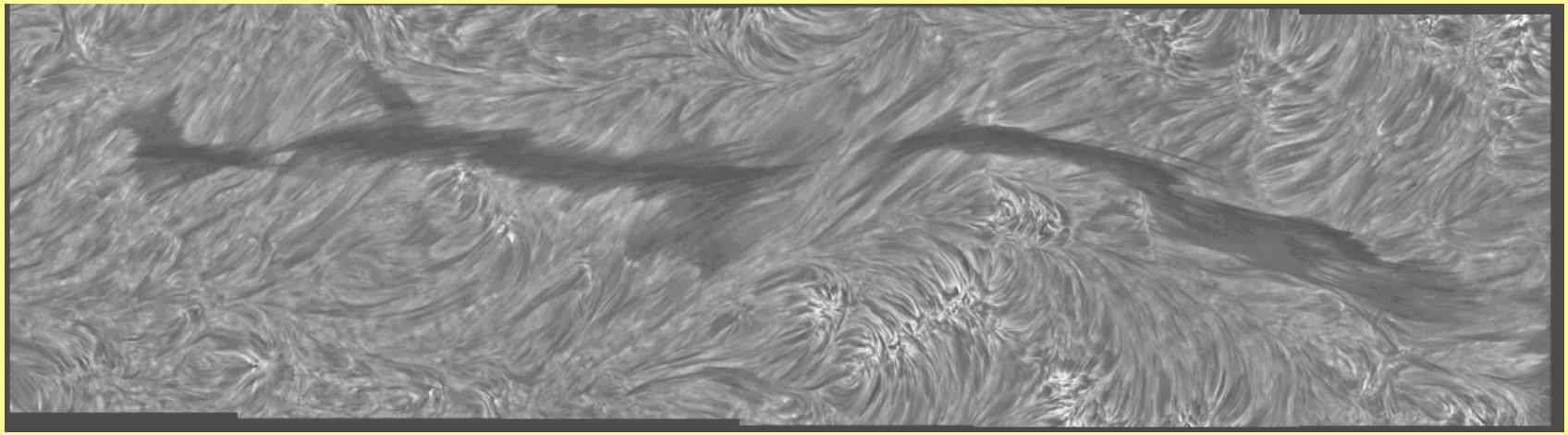
Does a Canopy Exist -- is the concept correct/useful ?

What is ratio of network - intranetwork flux ?

What is effect of cell flux on canopy ?

Need observations/interpretations

In H_{alpha} - see many horizontal fibrils

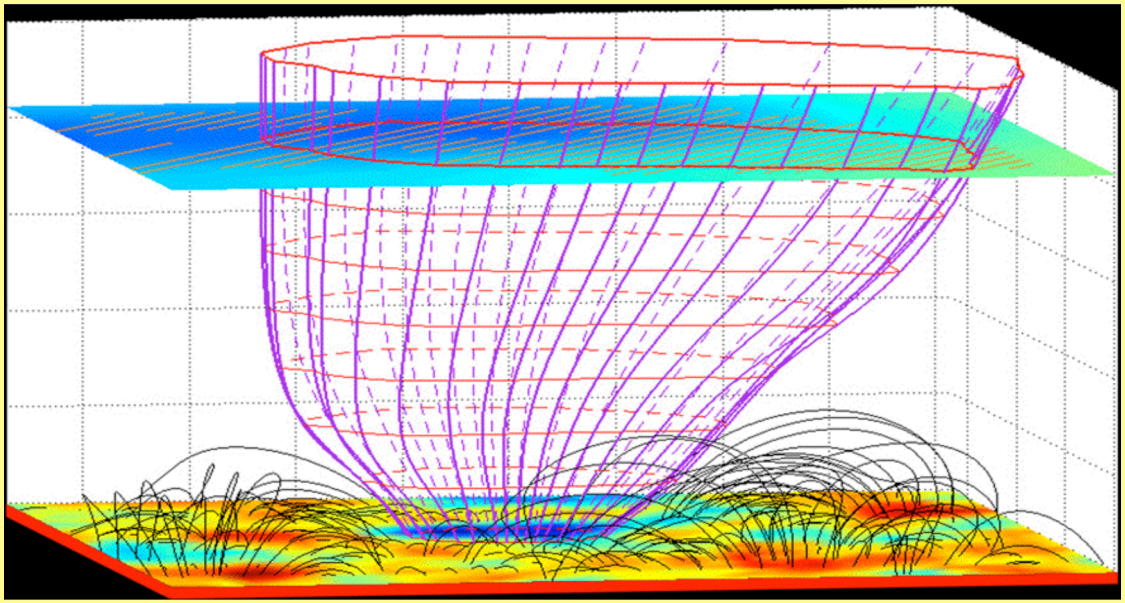


If intranet flux small/small-scale, **overall canopy preserved**

If larger, then **disrupt canopy** & break through

Whole structure much more complex & dynamic than Gabriel

Eckart Marsch



[Coupling photosphere -- solar wind]

Origin of fast solar wind in coronal funnels

Cf SUMER doppler shifts w. extrapolated **B**

--->

Funnel area (c. hole) expands by only 10 - not canopy-like

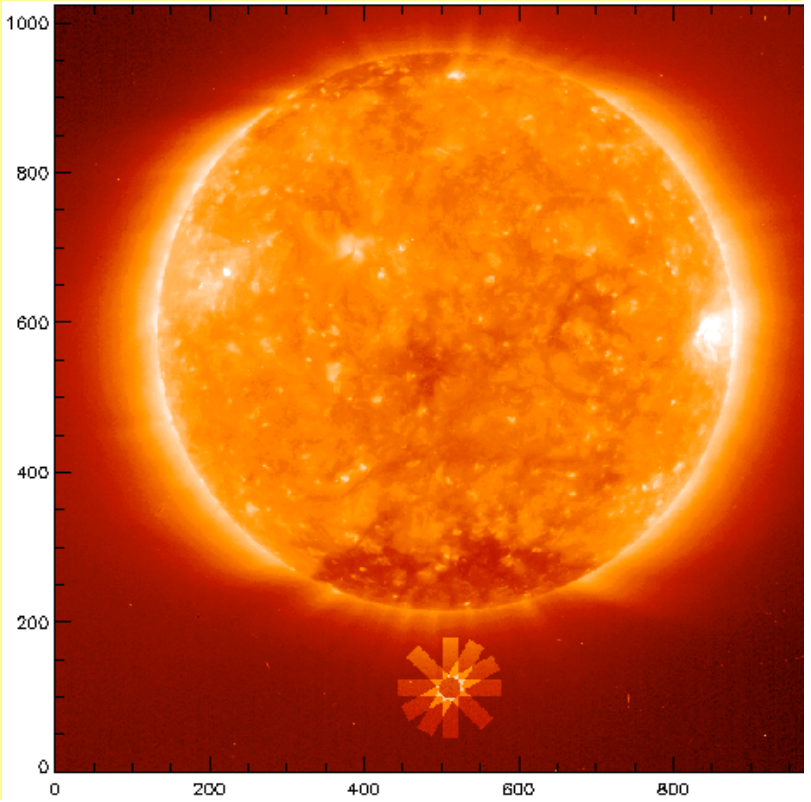
In quiet Sun --> ?? slow solar wind

2. Structure of Chromospheric B

Nour-Eddine Raouafi

Comprehensive review of ways of measuring chromospheric & coronal B
[Zeeman, Hanle, radio, extrapolation]

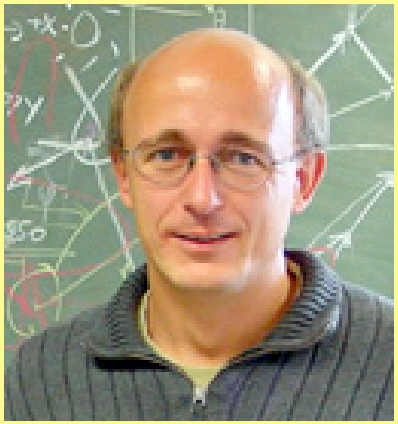
Hanle with SUMER (O VI 1032 Å) in polar coronal hole at ~1.3 $R_\odot$ **-->B=3G**



Achim Gandorfer

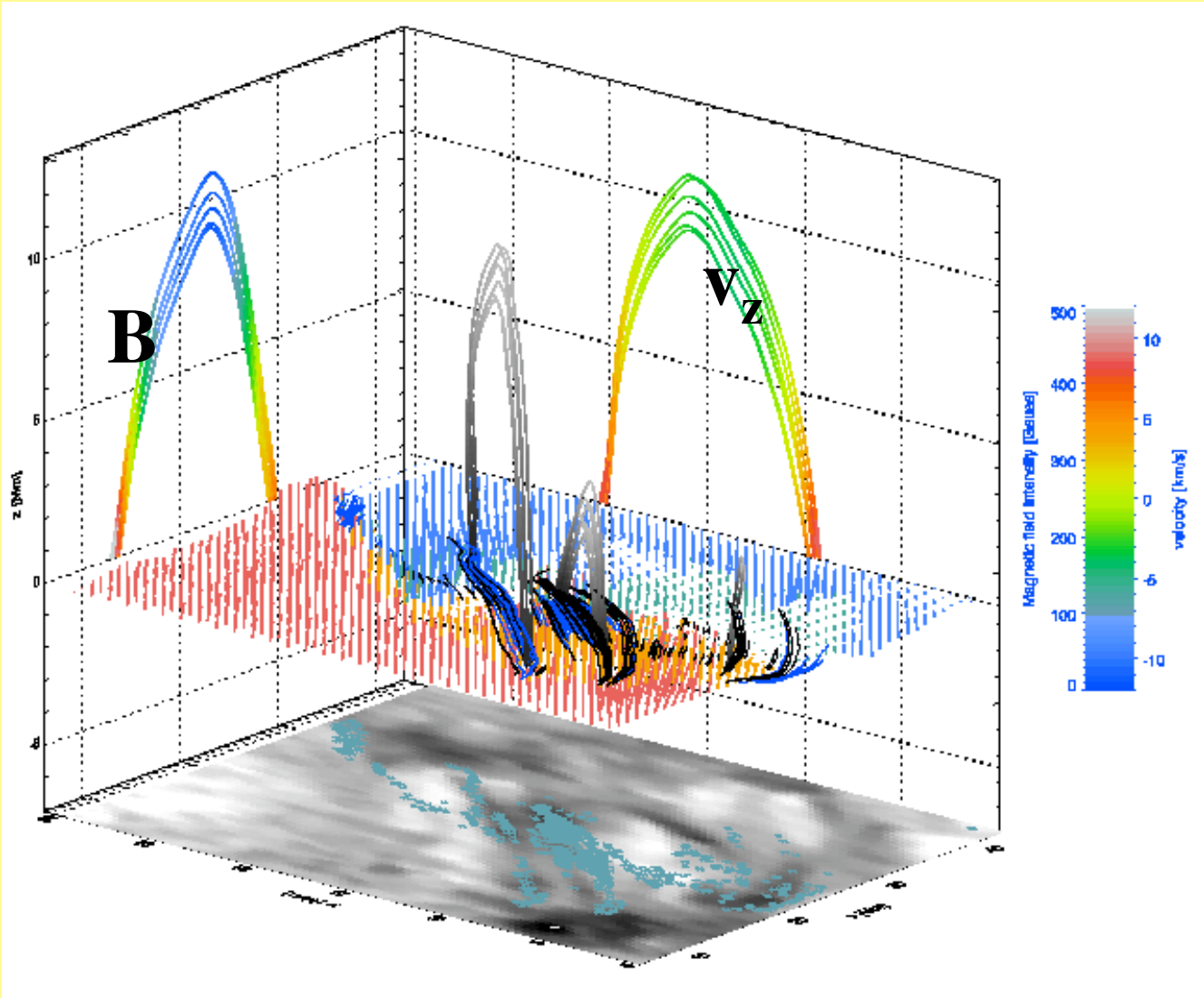
UV polarimetry from ground is key to chromospheric B [esp. CaI 4227]

Andreas Lagg



-- reviewed
canopy & spicules

B and v in emerging flux region

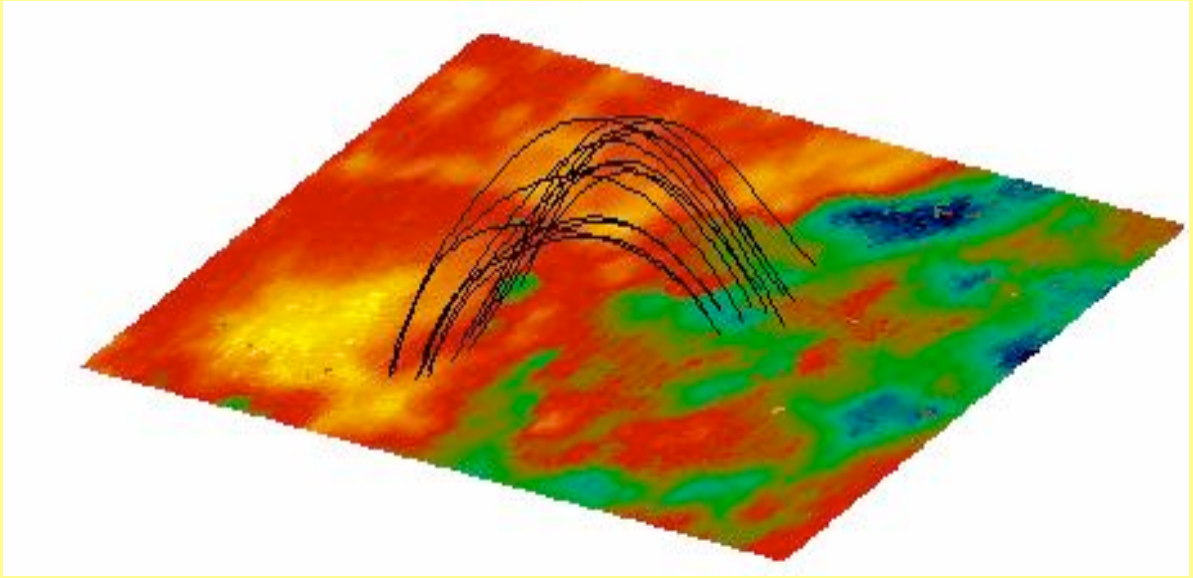


--> Huge potential of Stokes polarimetry (He 10830)

Very important to compare w models:

Thomas Wiegelmann

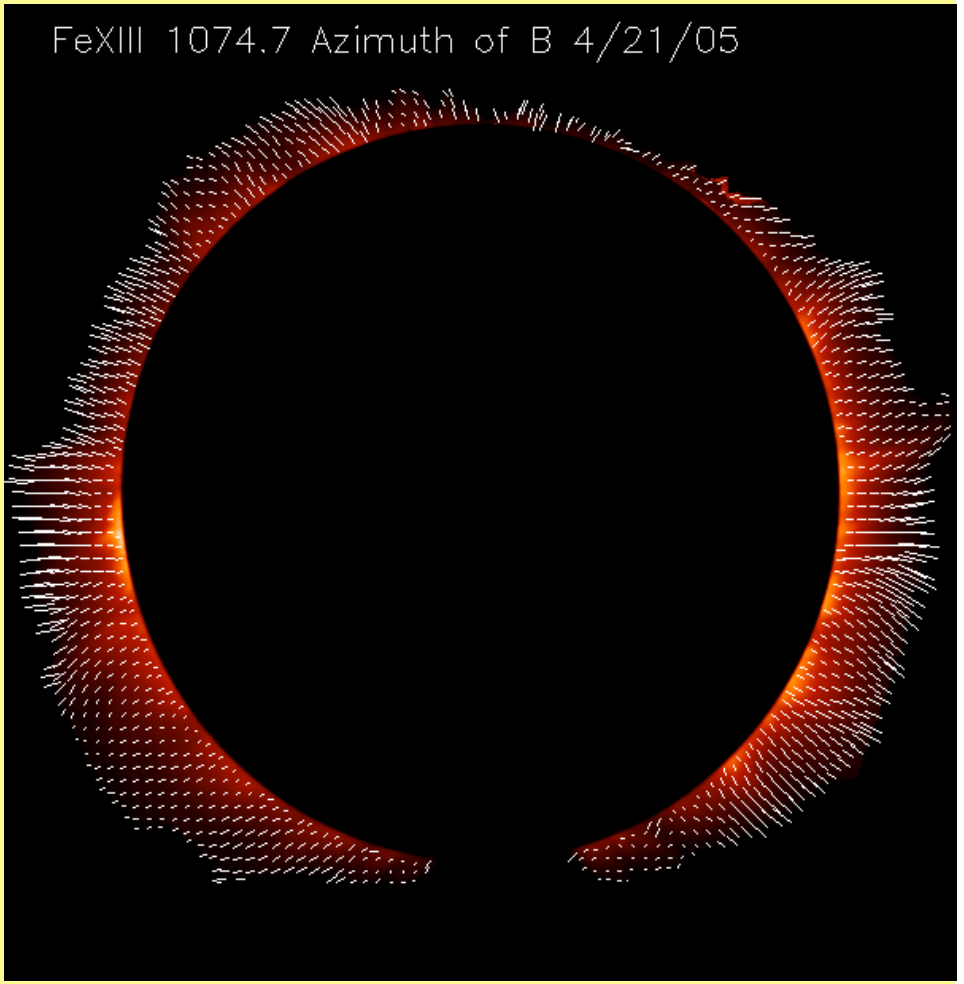
nonlinear force-free fields give best fit with observed loops



Non-linear force-free reconstruction

3. Structure of Coronal B

Steve Tomczyk -



Showed how to use coronal emission lines to measure Stokes parameters:
Best lines in infra-red
-- esp Fe XIII

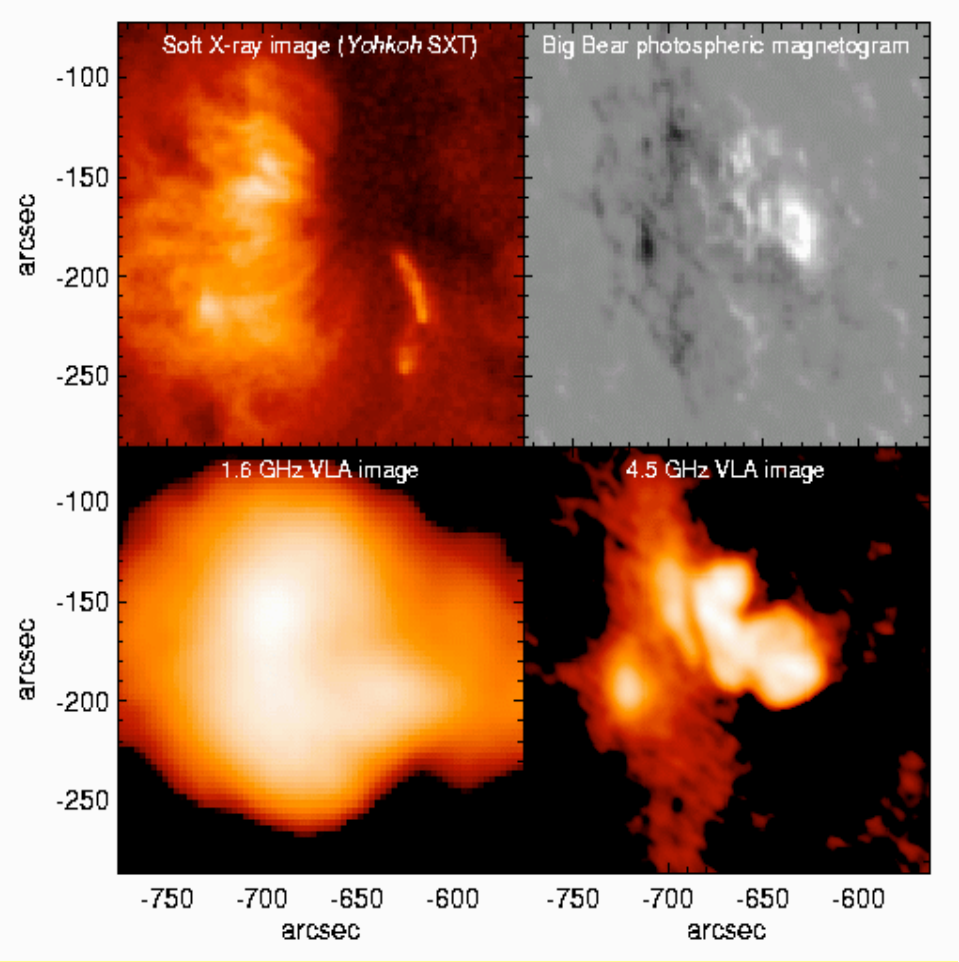
Need a dedicated large (1m) coronagraph

Stephen White - Review radio techniques

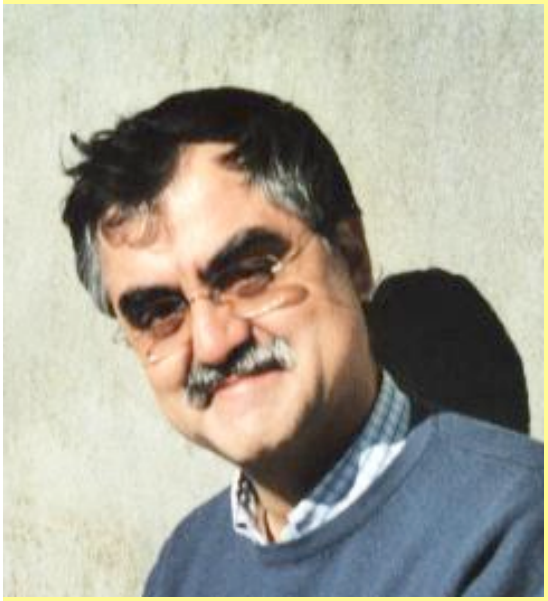
For active regions
can determine **coronal B > 300 G.**

--> 3D information on B on disc
(since optically thick) --
[uses B extrapolations to determine heights]

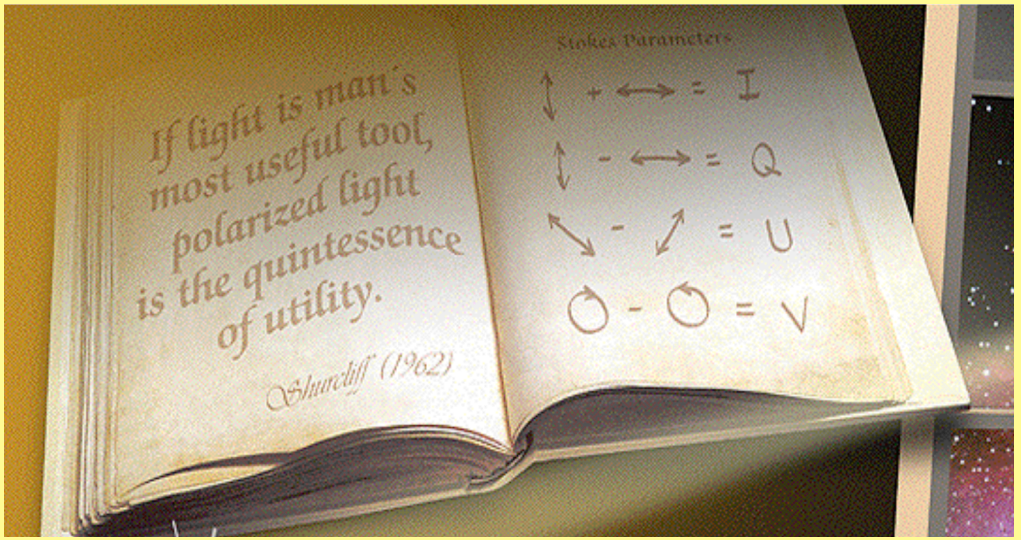
So complements IR measurements on limb B < 20 G



Javier Trujillo



Masterly case for EUV spectropolarimetry
-- using Hanle effect to measure **B** in t.r. & corona



Need to put a high-sensitivity UV/EUV polarimeter in space

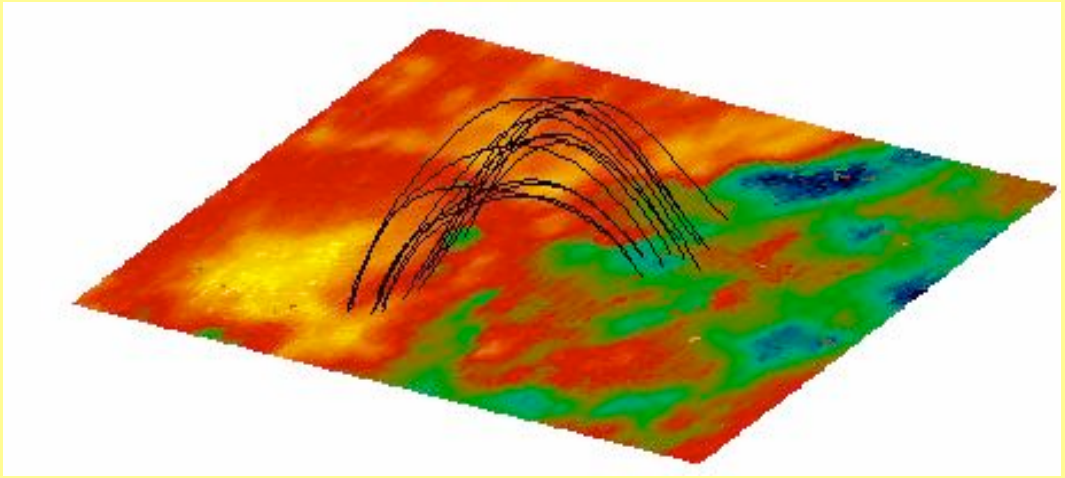
Maxim Kramer

Suggests that coronal Hanle and/or Zeeman data
\+ $\bullet\mathbf{B} = 0$ can be used to construct non-potential component of coronal **B**

Theory of coronal B

Thomas Neukirch -

Compared different methods for nonlinear force-free fields -- **Wiegelmann** optimisation best



Non-linear force-free reconstruction

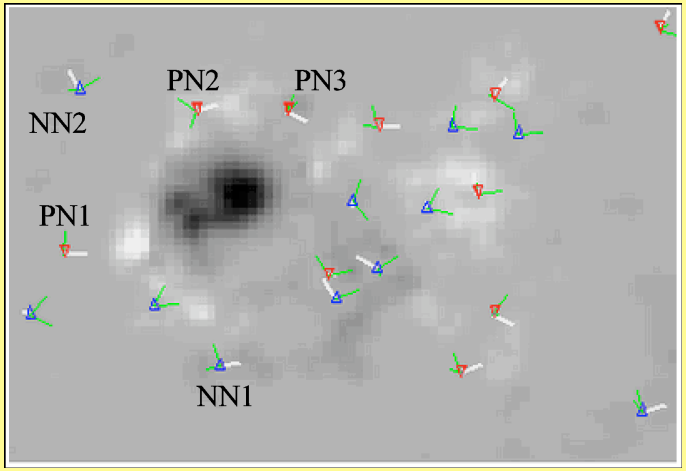
In future:
Need better observations (**SOLIS, Solar B, SDO)**

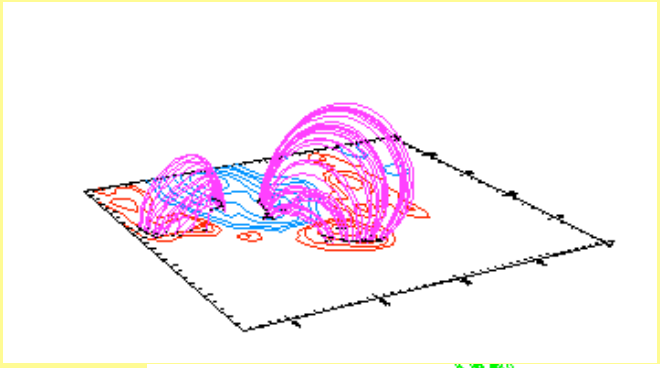
Need **fast and robust methods**

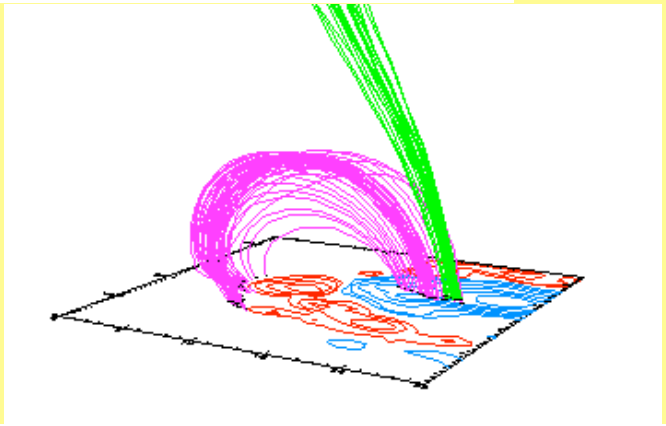
Need deal with **noise in data and non-force nature of photosphere**

Stephane Regnier

Followed evolution of active region [nonlin fff] -
Photospheric motions and complex topology are precursors of flaring







Coronal Topology

Pascal Demoulin

1. Model photo^{c} B in terms of discrete flux patches:

Skeleton - set of **separatrix surfaces** - divide corona

Separatrices intersect in **separator** - joins null points

Flux transfer occurs by **separator reconnection**

2. Generalise to continuous field distribution :

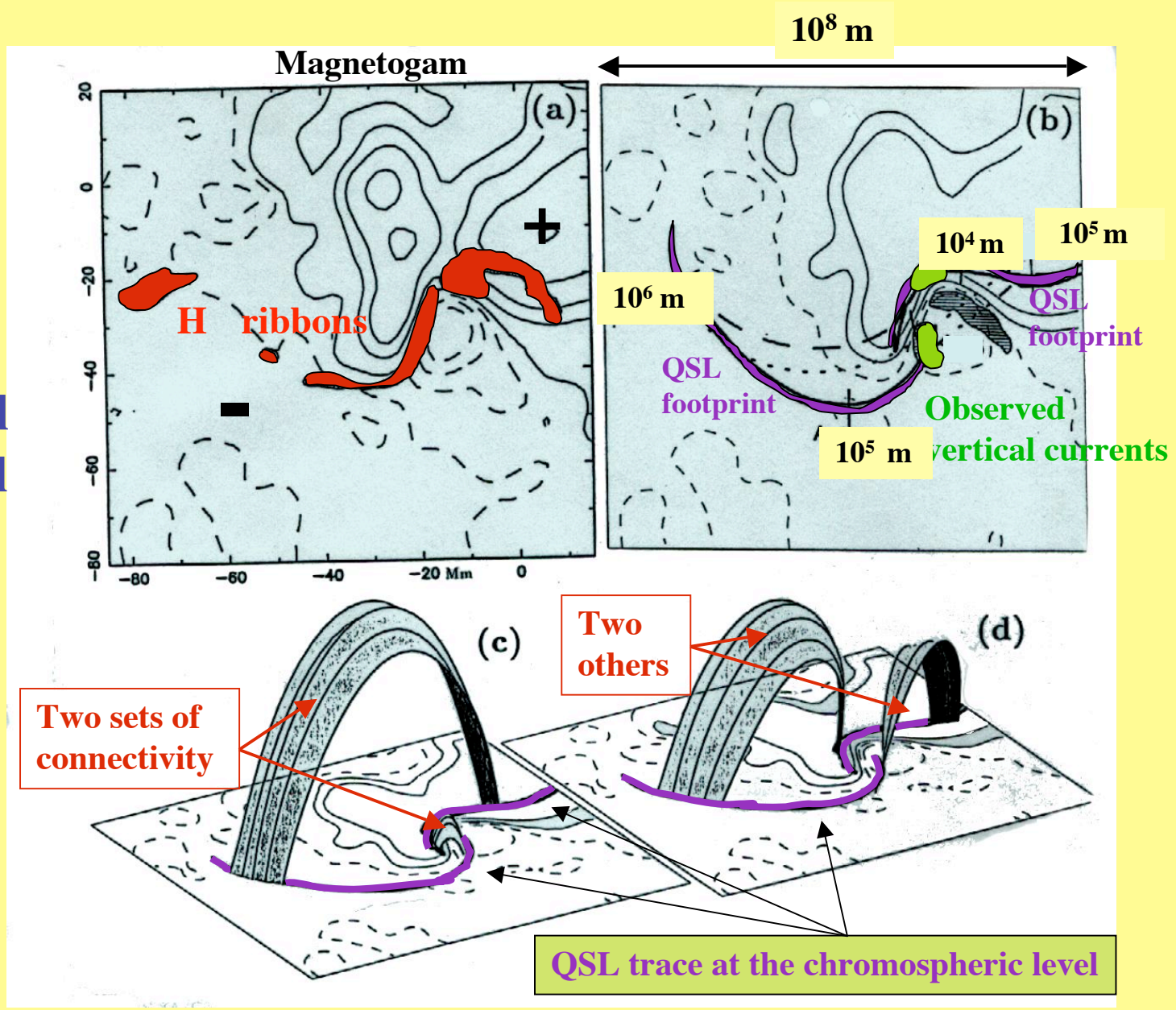
Discontinuities in mapping of feet → **strong gradients**

Separatrix → **Quasi-Separatrix Layer**

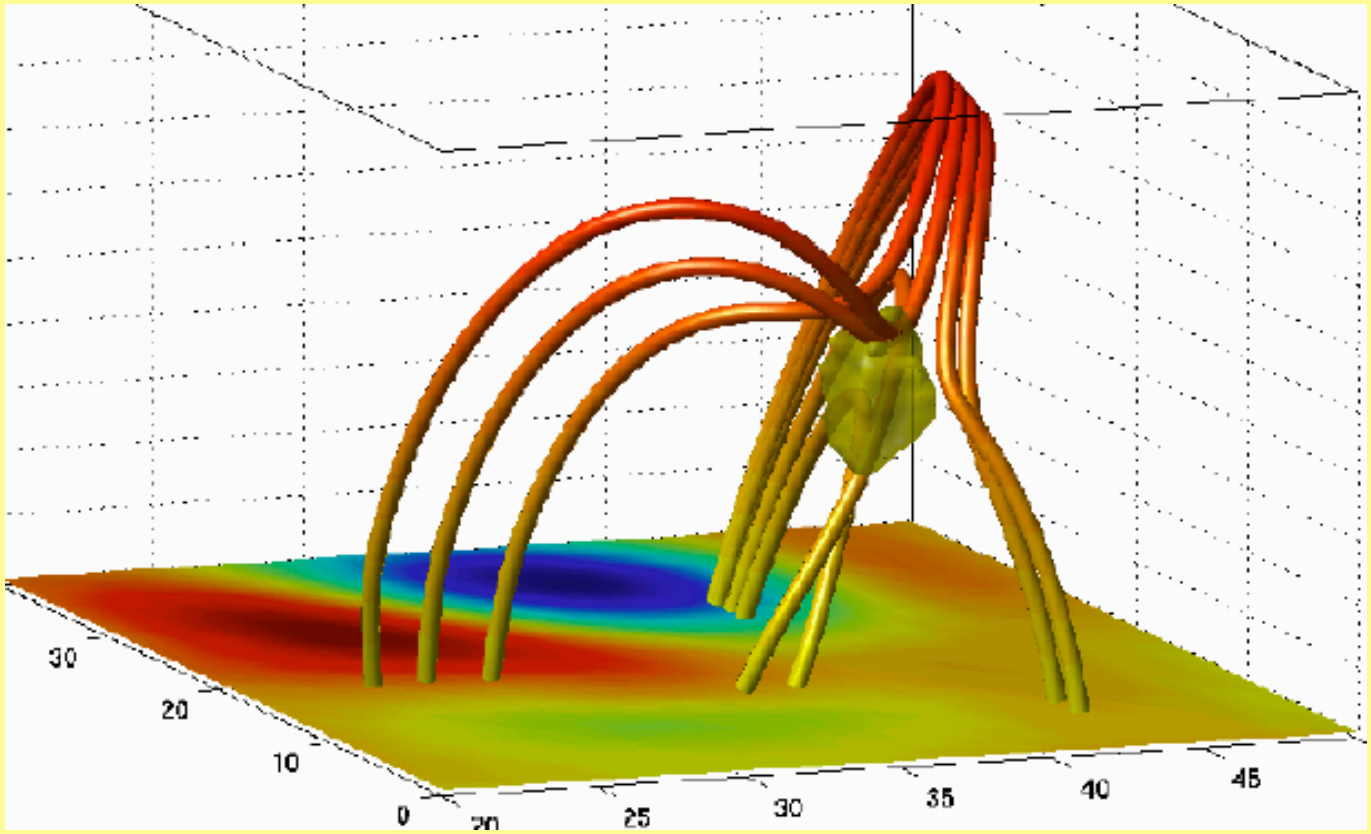
Separator → **Quasi-Separator**

Some flares occur at separatrices, some at QSL's

(Mandrini et al
Démoulin et al
Aulanier et al)



Joerg Buchner

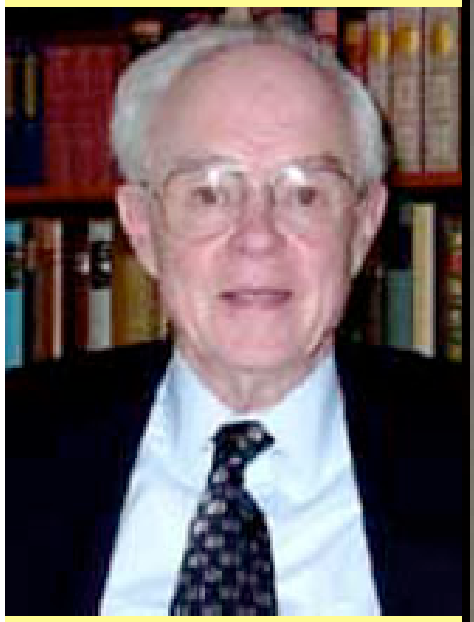


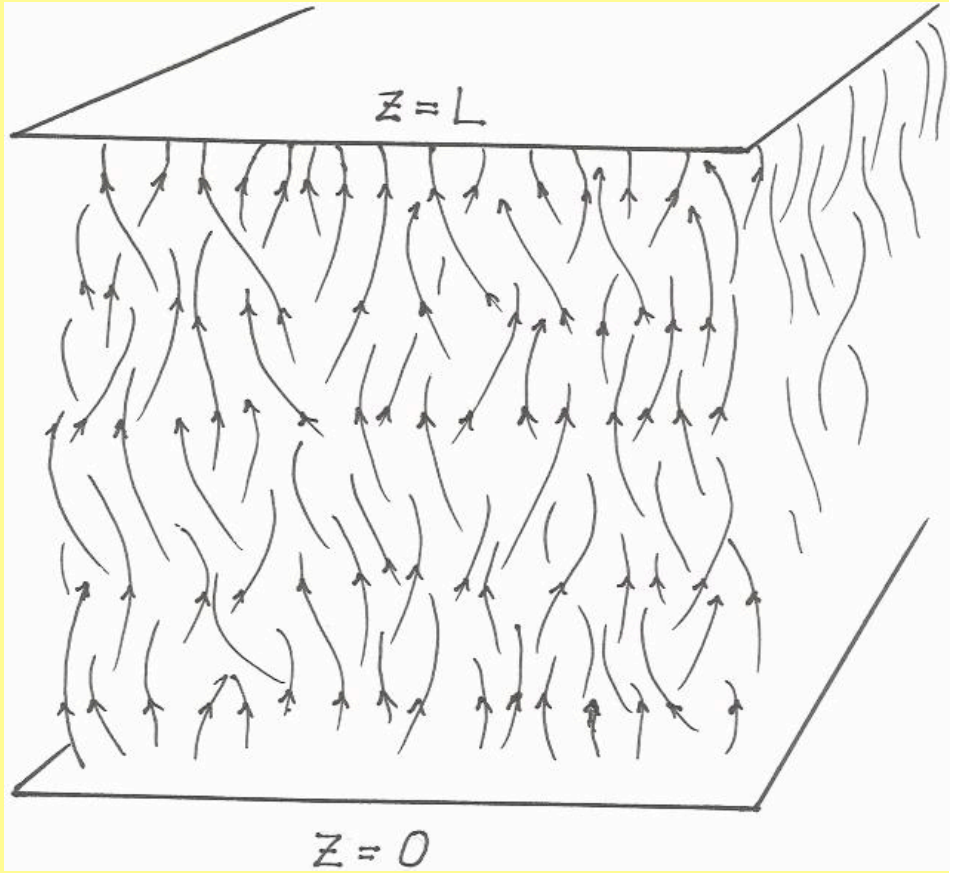
Slow footpoint motions in numerical MHD simulation of XBP, j sheet, coronal hole -->

Evolution through piecewise nonlinear fff with current sheets on separatrices/QSLs

4. Coronal Heating

Gene Parker





-- nano/pico-flares -

impulsive recon^{n} in j sheets

from braiding.

-- granules are source energy, waves not effective

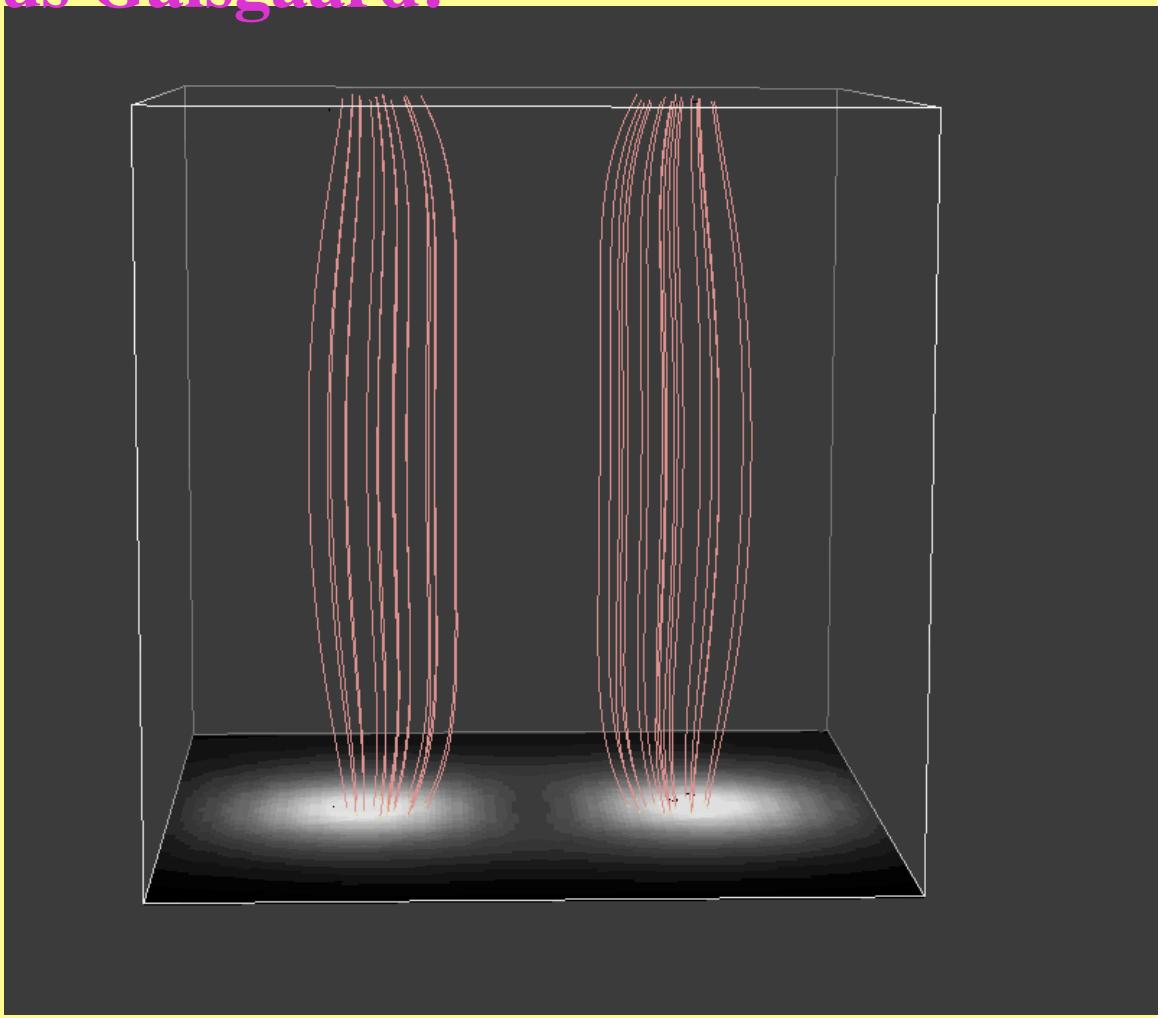
Coronal tectonics

-- refinement of Parker-braiding
-- magnetic carpet enhances formation of current sheets

Ineke deMoortel & Klaus Galsgaard:

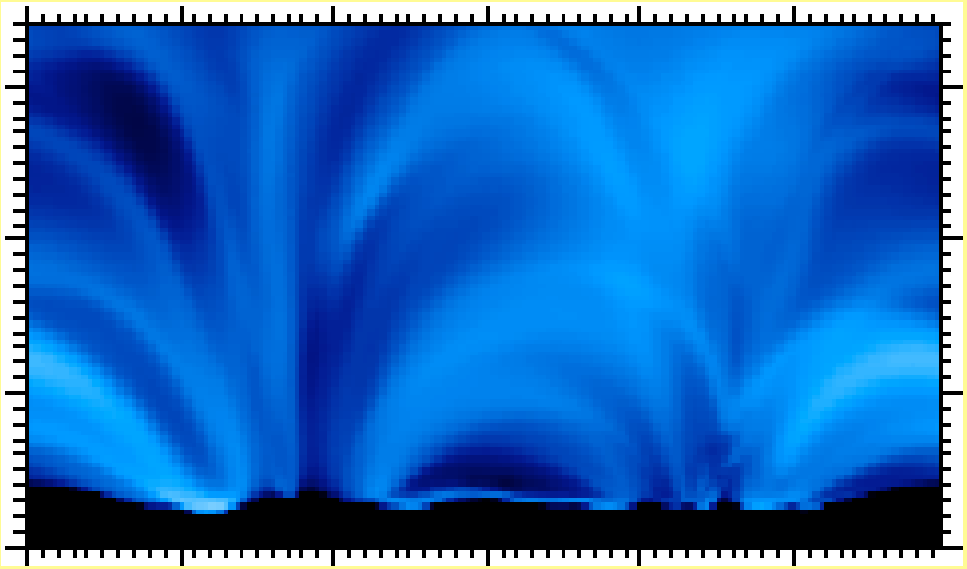
Twist normal tube --> weak j.

If feet are in localised flux patches --> **Separator or quasi-separator sheets**



Hardi Peter

Synthetic spectra from Gudiksen's 3D numerical experiment on braiding/tectonics



Good match with observed doppler shifts & emission measure

Rekha Jain - model by forced reconnection

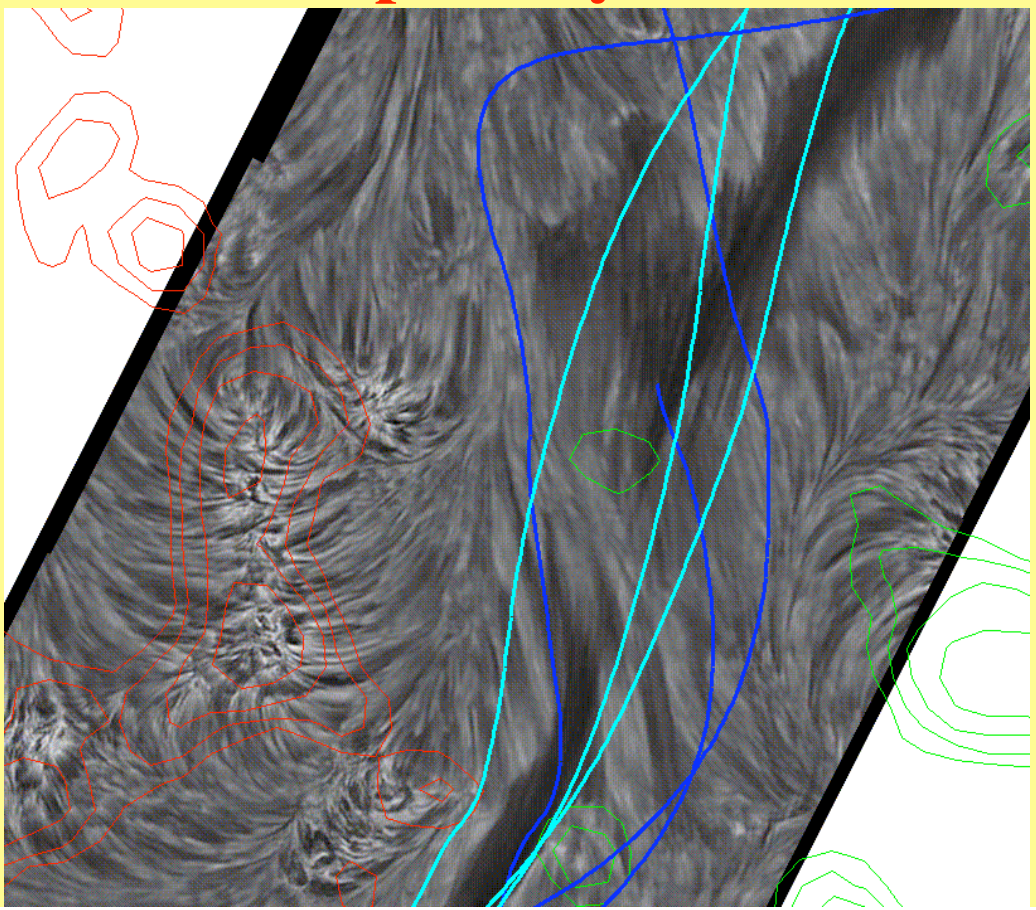
Tohri Shimizu - structure of shocks in Petschek recon.

5. Prominences -- for long an enigma

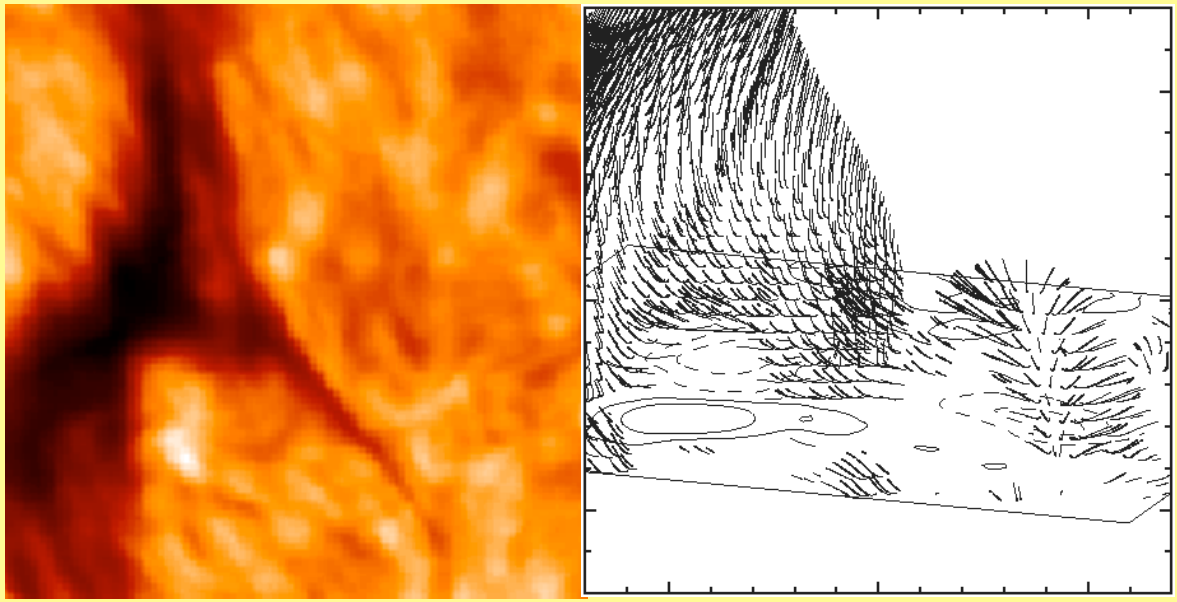
Laura Merenda & Arturo Lopez - measured **B** in prominences

Aad van Ballegooijen

Nonlinear fff models for global structure
+ barbs as B-lines ending at parasitic polarity



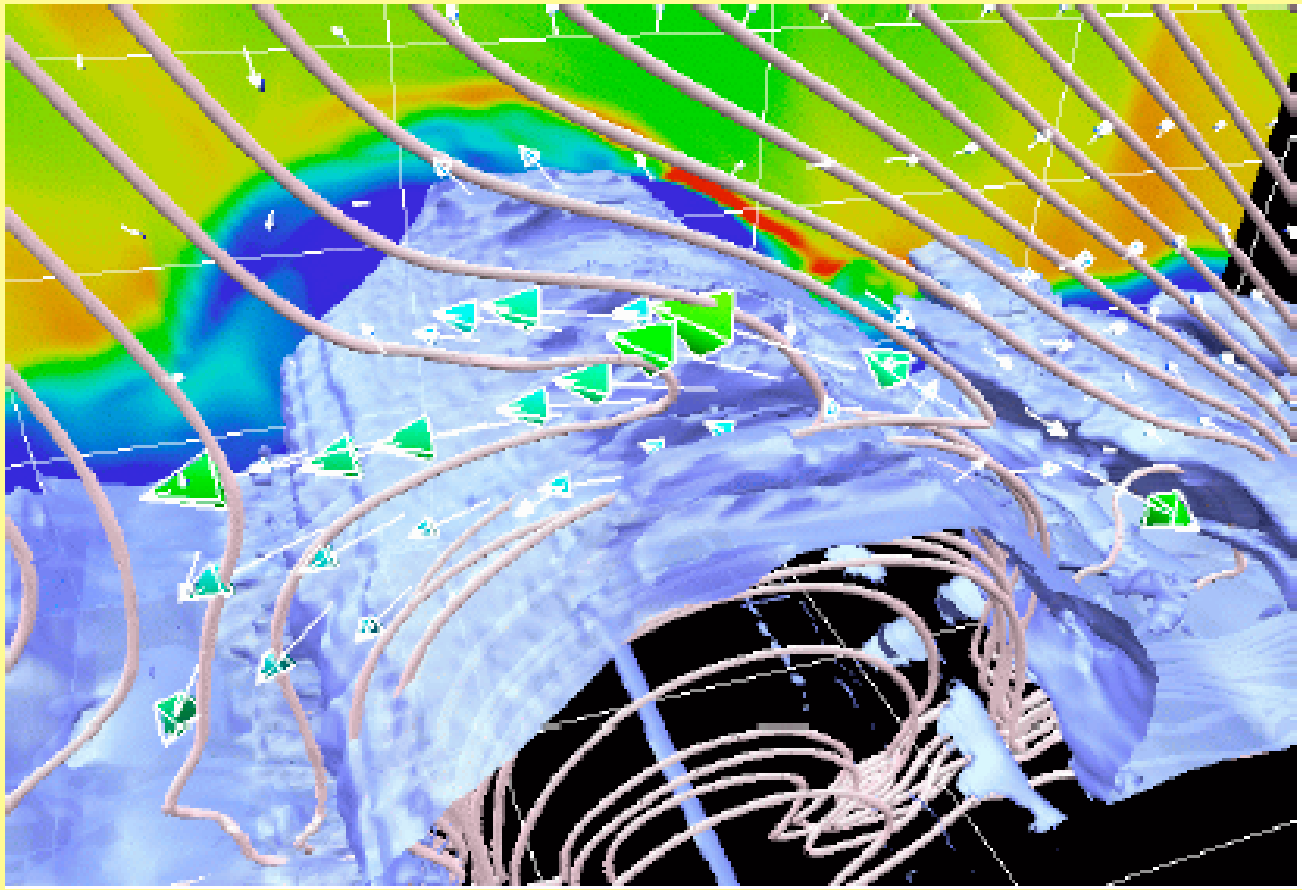
But Brigitte Schmieder -
Barbs are bald patches [magnetic dips in photosphere]



?? Still puzzled about barbs
Need t-evolution of magnetogram

6. Emerging Flux

Hiroaki Isobe



R-T instability--> filamentation

& fast impulsive bursty reconnection

Etienne Pariat

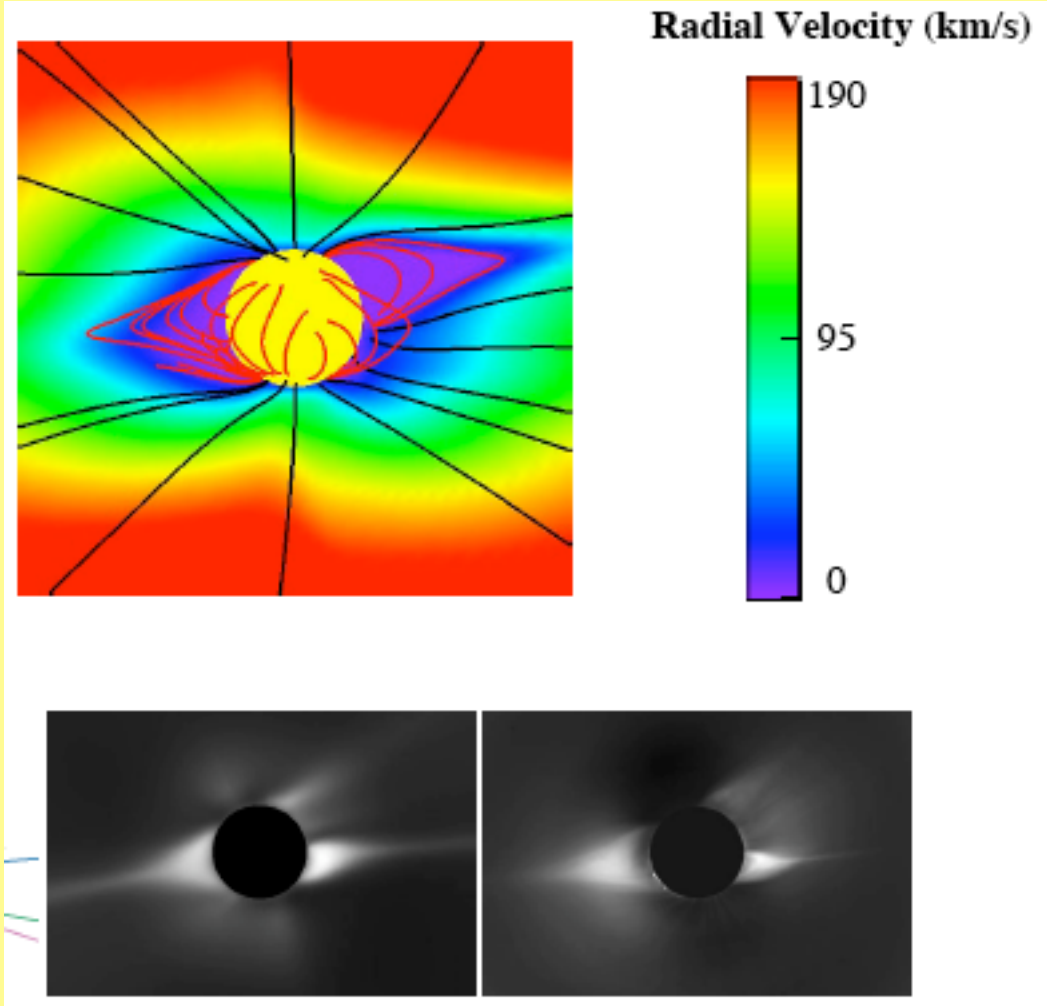
In EFR, linear fff model -->
Several bald patches as serpentine field lines
-- dips get rid of dense plasma by reconnection
(Ellerman bombs)

Klaus Galsgaard

-- flux emerges through
convection zone
and **reconnects with**
overlying coronal magnetic
field

Jon Linker **Impressive account of structure of large-scale corona**

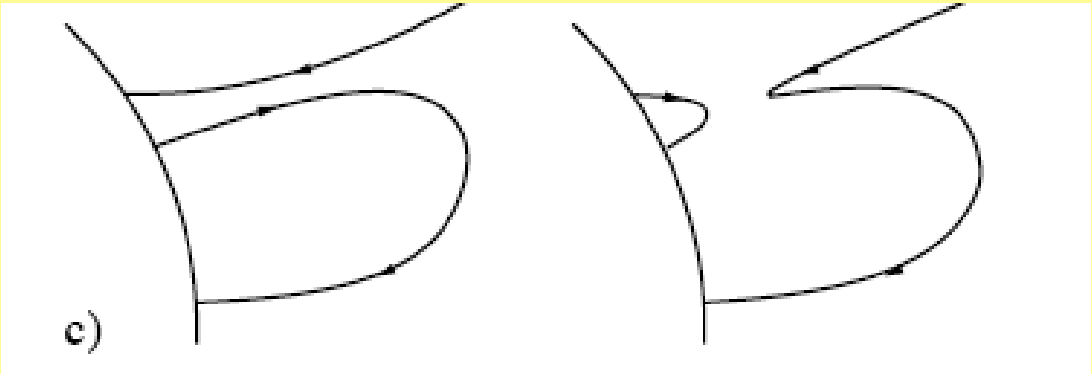
1. Steady polytropic MHD models

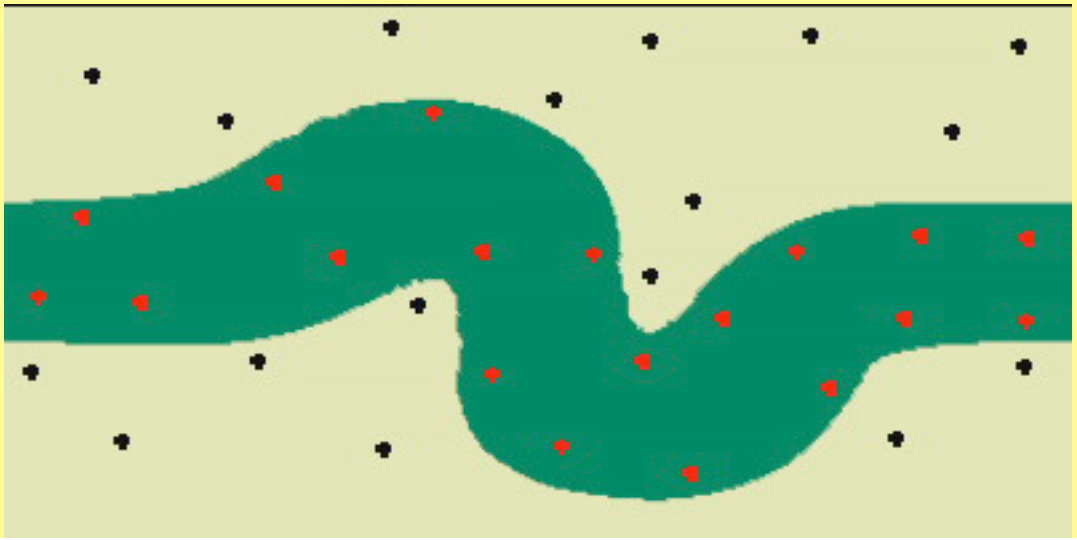


?? Effect of better energy eqn (vel^{y} too slow, hole dark)

2. Non-steady models

Differential rotation + t-dependent evolution + -->
Interchange and disconnection reconnection of coronal hole





7. Eruptive Instability (flares & CME's)

Lyndsay Fletcher

-review of latest results from flare observations

[flare predictions,
weak particle acceleration before,
problems w. coronal electron acc^{n,}
occurrence of flares in dense medium]

Alexander Nindos **Study of active region evolution**

Calculated H_{rel} with linear force-free alpha-best method
Most active regions with large H_{rel} produce CMEs
-- in future nonlinear FFF when fast methods

Yuhong Fan

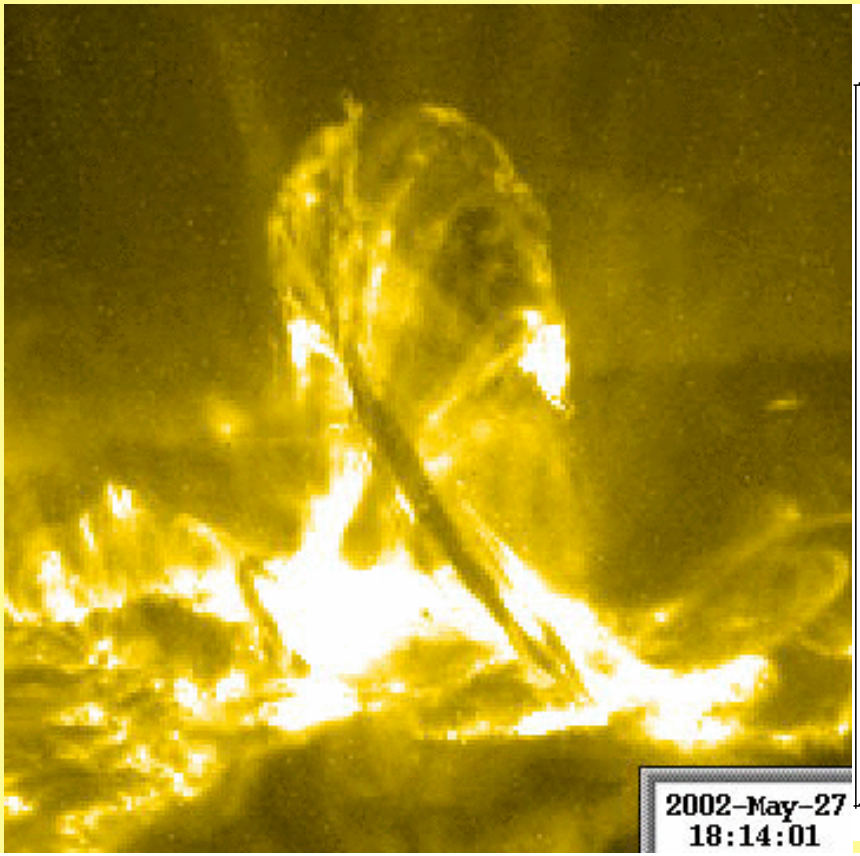
Emergence of flux rope into a potential arcade

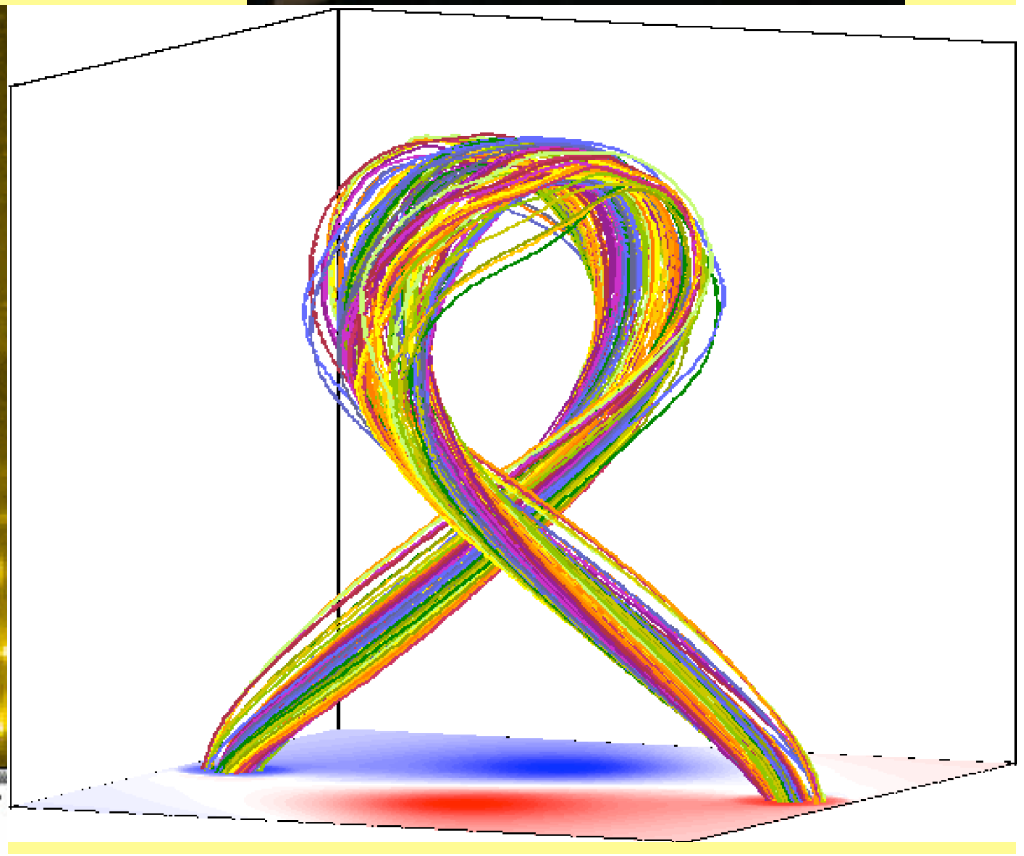
--> CME

Eruption due to magnetic catastrophe when twist > 3.4

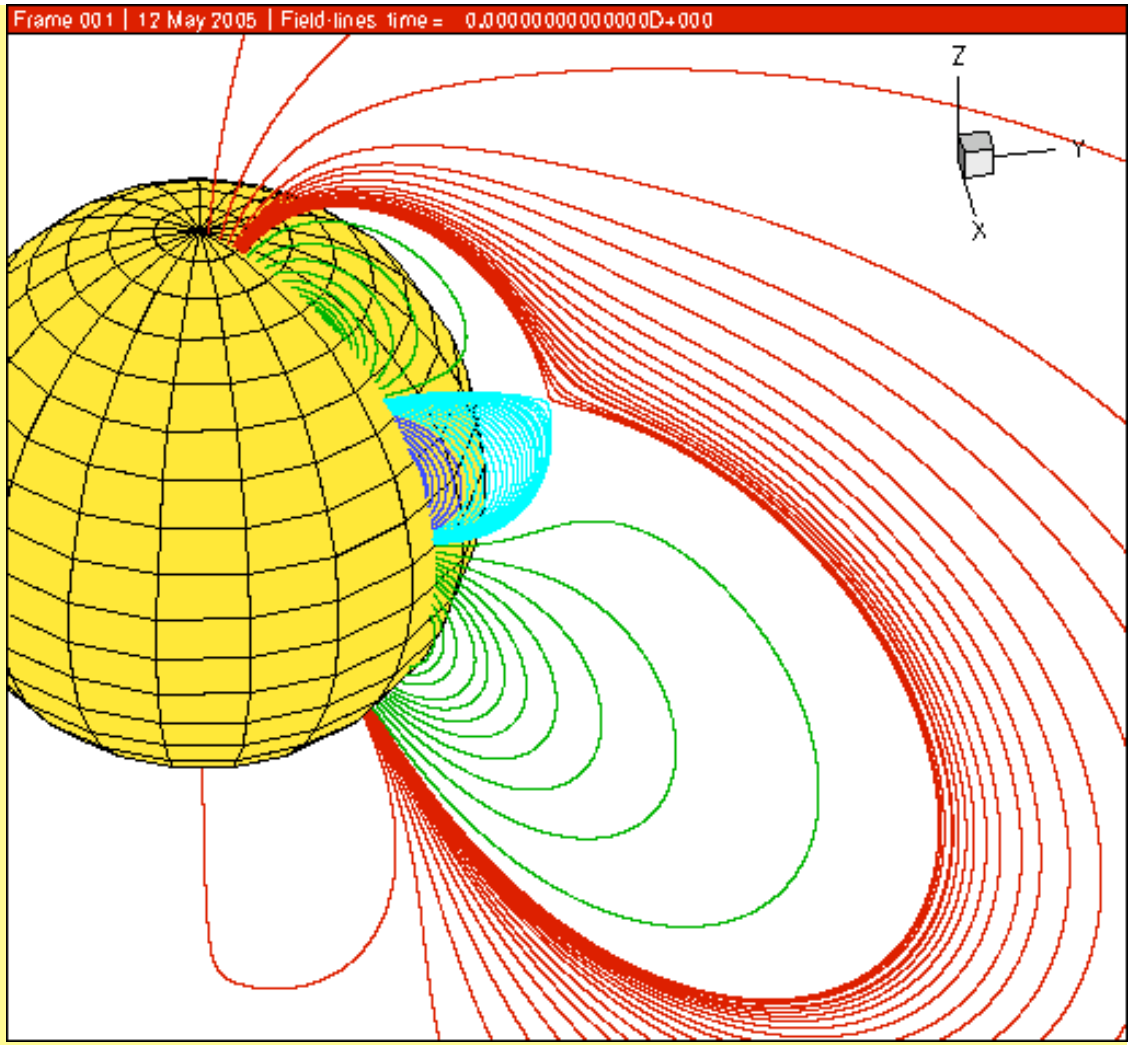
Tibor Torok

Similar model for kink, with different flux tube/ overlying field





Spiro Antiochos
- breakout model



Filament takes off before flare but ?? timing filament eruption/CME

Need nonpotential B in filament channel, but ?? sheared arcade or twisted loop

Need overlying field, but ?? how does eruption start

Other Suggestions

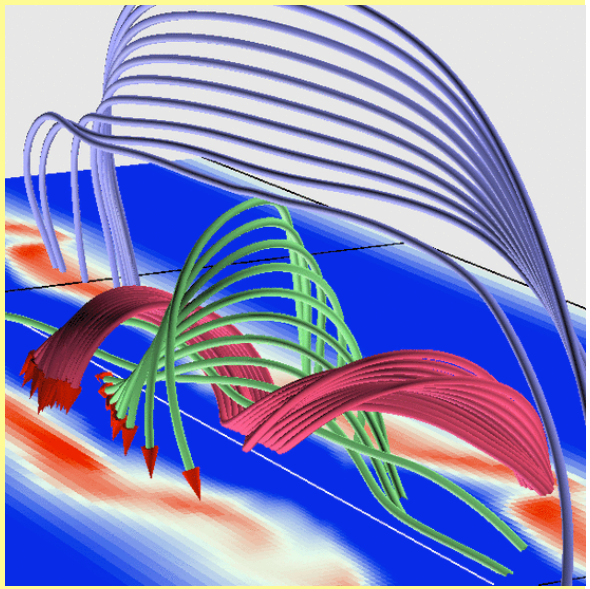
Bernhard Kliem:

CME's initiated by **torus instability**
-- don't need twist in flux tube

Kanya Kusano:

"Reversed shear model" (3D resistive MHD)

Tmi --> sigmoid as a relaxed linear fff
→double reconnection
→ eruption / flare



So … ?

All models --> flare loops, but ?? initiation of eruption

?? Several or one mechanism for eruption

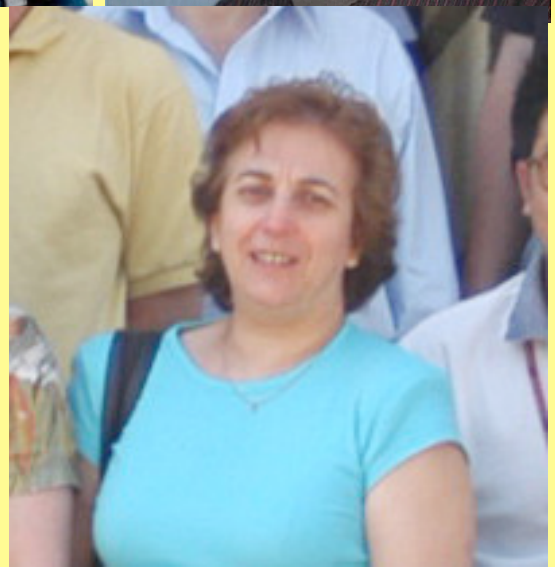
Several viable ones now proposed

But which has the essentials ??

Need more realistic initial configurations for num. expts

-- focus on obs^{l} conseq^{ces}

Anik de Groof & Daniel Muller



Observations & theory of coronal rain as thermal instability --

Downflow slower than freefall because of compression ahead of blobs

Erwin Verwichte

Tadpole waves - fast magnetacoustic kinks

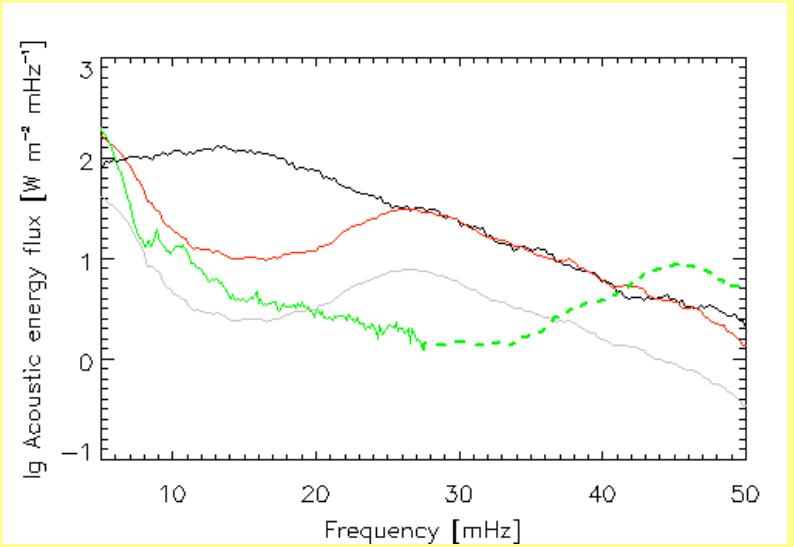
Cristina Mandrini

Interplanetary clouds - same flux & H_m as erupting a.r.'s

Mats Carlsson

8. Waves

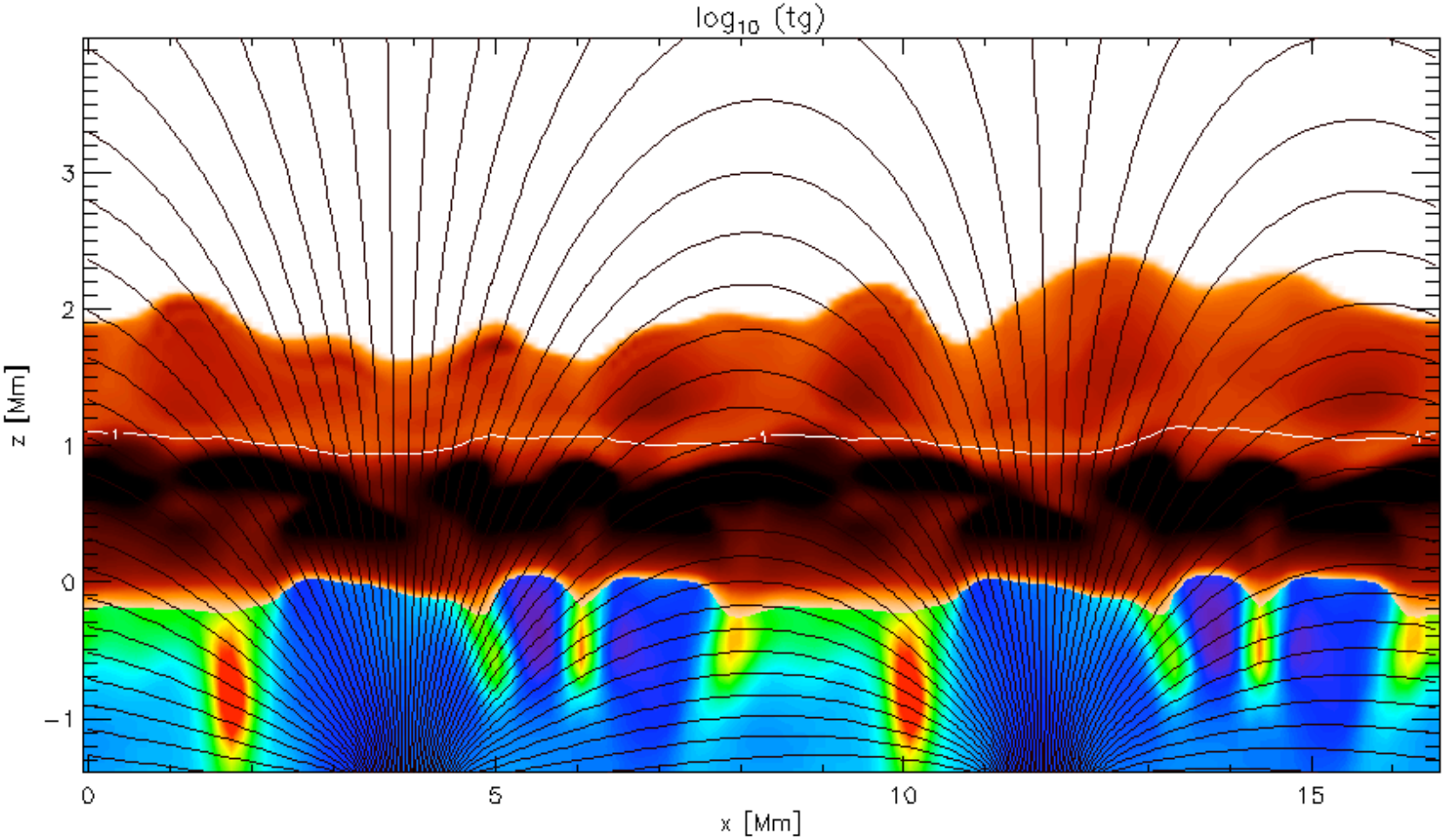
Impressive review of observations/theory of chromospheric waves



(Fossum & Carlsson,2005)

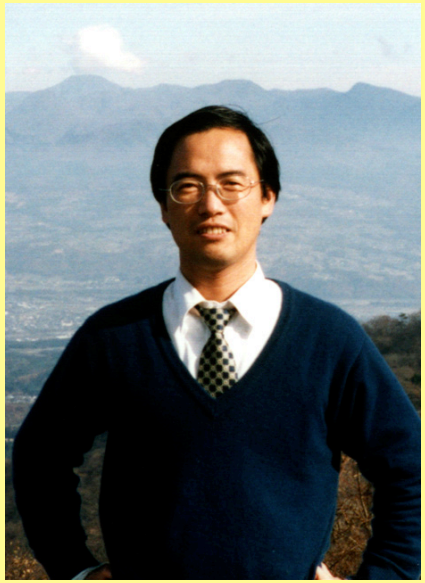
- **Ca II grains** explained by acoustic waves
- **3min waves** present already in photosphere
- Non-magnetic chromosphere very dynamic.
- Acoustic waves power **factor 10 too small** to heat chromosphere

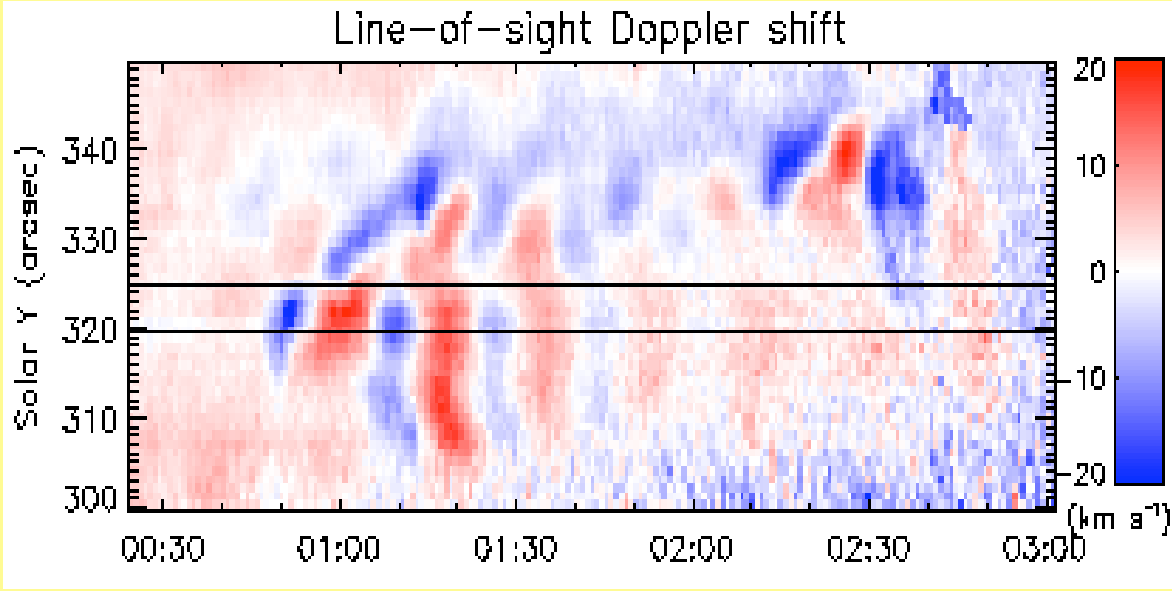
Simulation of Magnetic Chromo (2D) Hansteen



- Chromosphere pervaded by waves
- Mode conversions where C_s=C_a

Tongjiang Wang





Comp^{ve} review coronal oscillations:

In TRACE (transverse global kink)

SUMER (standing slow-mode)

EIT/TRACE (prop^{ng} slow-mode)

More realistic simulations / detailed observations

--> excitation & damping (??)

+ properties corona

i.e. Coronal seismology -- infancy !

Elena Khomenko

Numerical model waves in sunspot:

Fast-mode refracts back to the photosphere.

Slow-mode continues up to the chromosphere.

Dipankar Banerjee Detected long-period magac.waves in coronal holes at 50 km/s [wavelet analysis with CDS]

Malgorzata Selwa Oscillations in a coronal loop

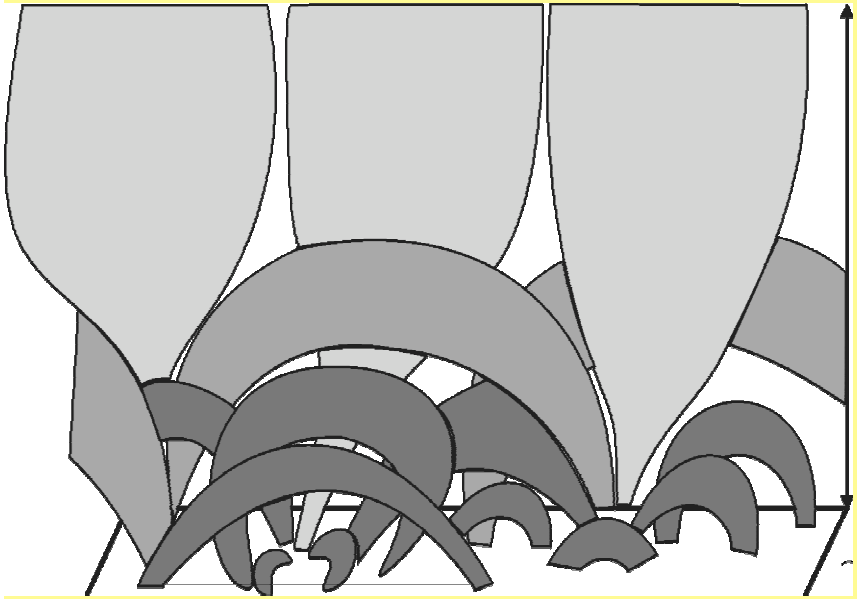
Tom Van Doosselaere Coronal loop oscillations

Thanassis Katslyannis SECIS observations of waves

Claire Foulon Pulsations in solar flares

SO, what do we have ?

A **3D multi–structured coupled dynamic magnetic** photosphere, chromosphere & corona on a wide **range of scales**



for which we need a strong coupling theory-observation & a wide range of talents - to take understanding to new level

In this we can all (as a community) play our part

FINALLY

THANK - Sami Solanki and his merry gang (Andreas, Bernd, Eckart, Manfred, Joerg + Queen Davina)

I HOPE --

We can communicate our sense of vitality to young European scientists of future.