Quiet Sun magnetic fields

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presented by Michiel van Noort

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QS Magnetic Fields

There appear to be two different populations
Network

- strong fields (>1kG)
- mostly vertical
- supergranular scale

Internetwork

- Weak fields (<1kG?)
- granular scale

How much flux is there?
How is it structured?
Where does it come from?

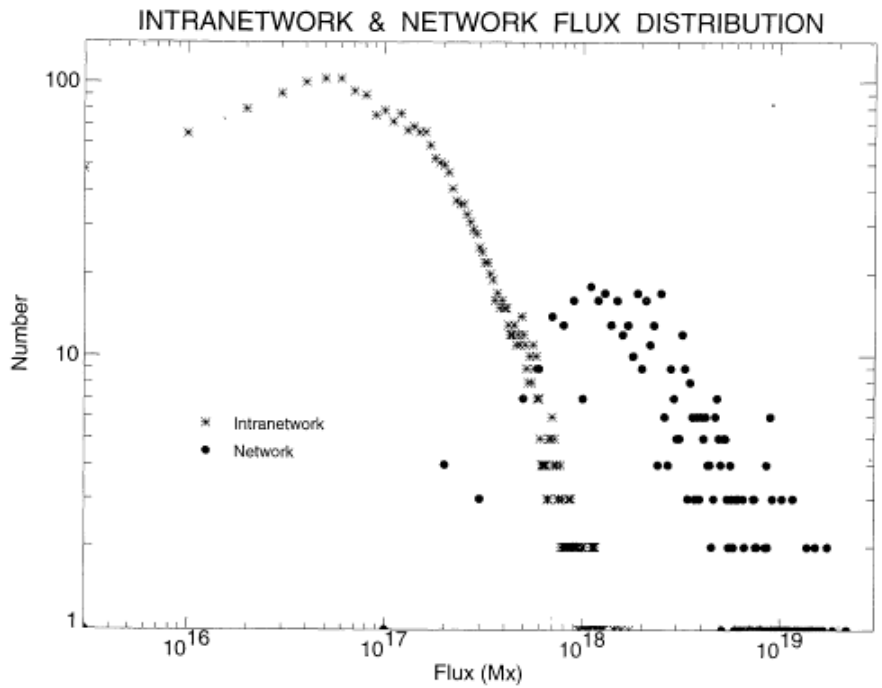

Fig. 3. Flux distributions for IN (asterisks) and network flux elements (dots).

Wang et al (1995)

Internetwork

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Livingston & Harvey 1971,1975	zeeman, optical	B~ a few G	
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Danilovic et al. 2010	Zeeman, forward mod., optical	<B>≈70 G at τ = 0.1, <B> ≈170 G at τ	predominantly horizontal
Stenflo 2010	line ratio technique		predominantly vertical to isotropic
Ishikawa & Tsuneta (2011)	Zeeman, inversions, optical	Bl=8.3G, Bt=7.1G	predominantly vertical
Shchukina & Trujillo Bueno 2011	Hanle, forward mod.	B≈160 G at z=60 km, B≈130 G at z=300 km	
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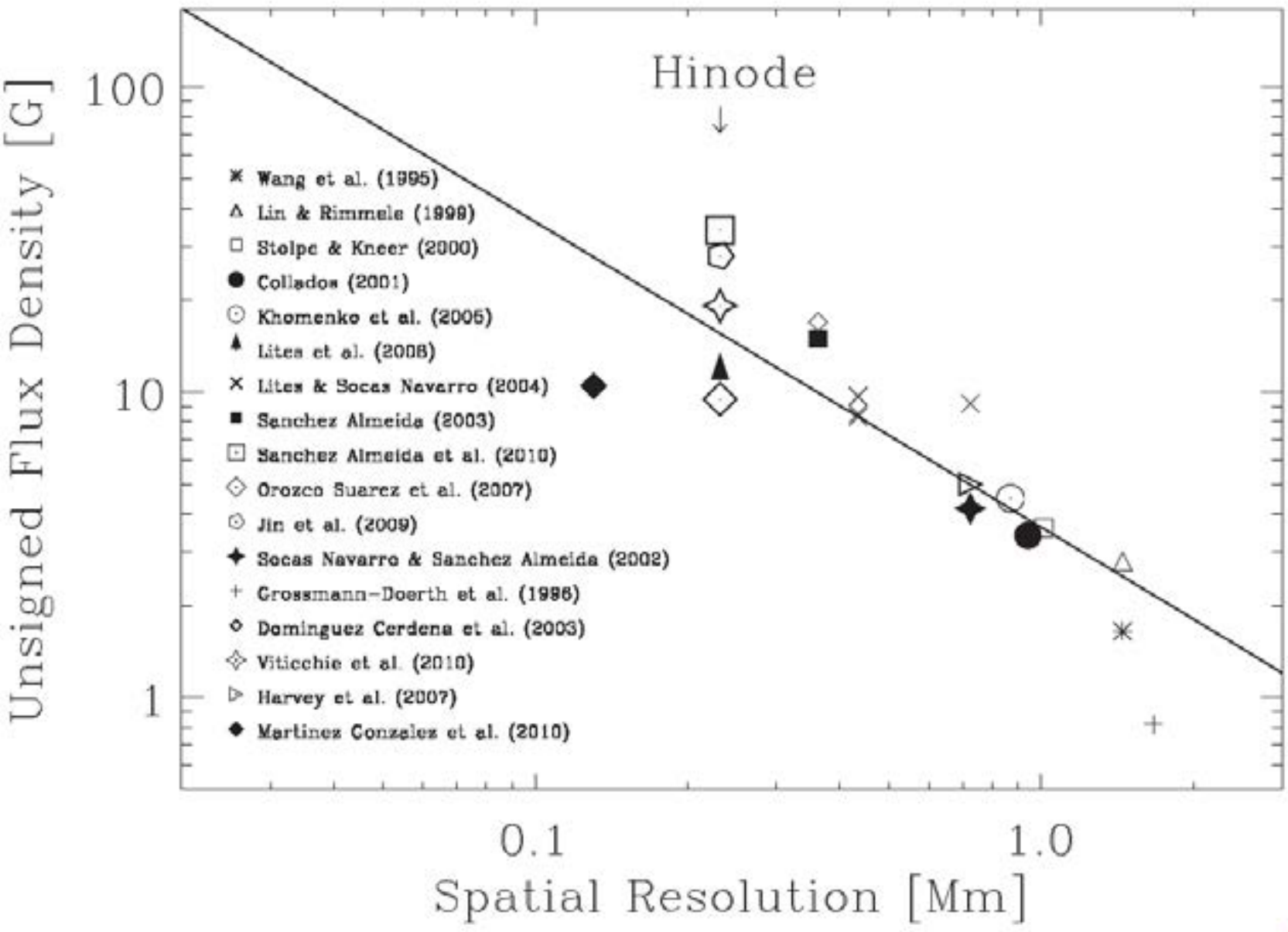
Asensio Ramos & Martinez Gonzalez	Bayesian analysis, optical		isotropic
	Zeeman, 2D inversions, optical	<B>=134G, <Bz>=74G, <Bh>=94G	close to isotropic

Average Flux Density



Sanches Almeida & Martinez Gonzalez (2011)

Diagnostics

Different diagnostics: don't agree

Zeeman

- Well known atomic physics
- Lots of signal
- prone to cancellation (resolution sensitive)
- Effects are line sensitive
- $\langle B \rangle$=1-200G

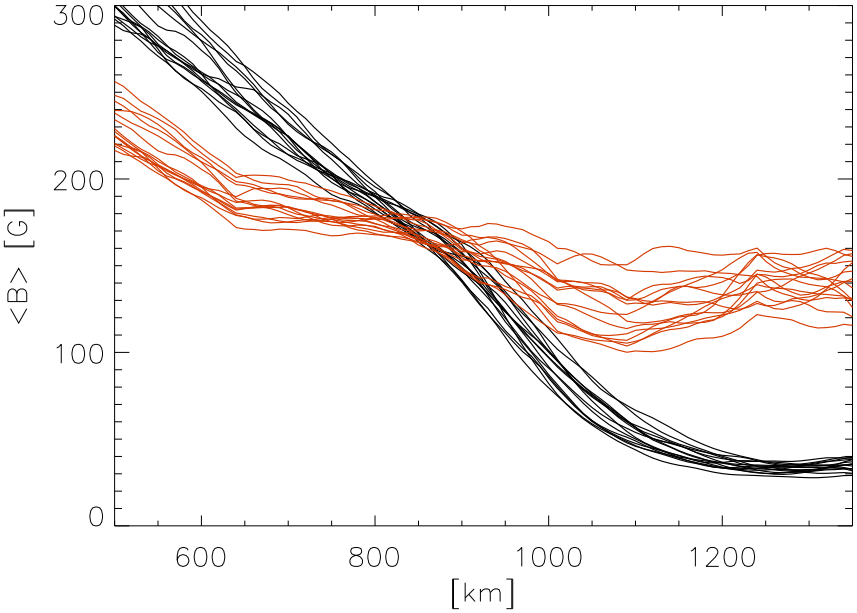
Hanle

- Complicated atomic physics
- weak signal
- insensitive to cancellation (resolution independent)
- $\langle B \rangle$=160G @ 60km, 130 @ 300km

How to reconcile (and with MHD)?

Hanle vs Zeeman

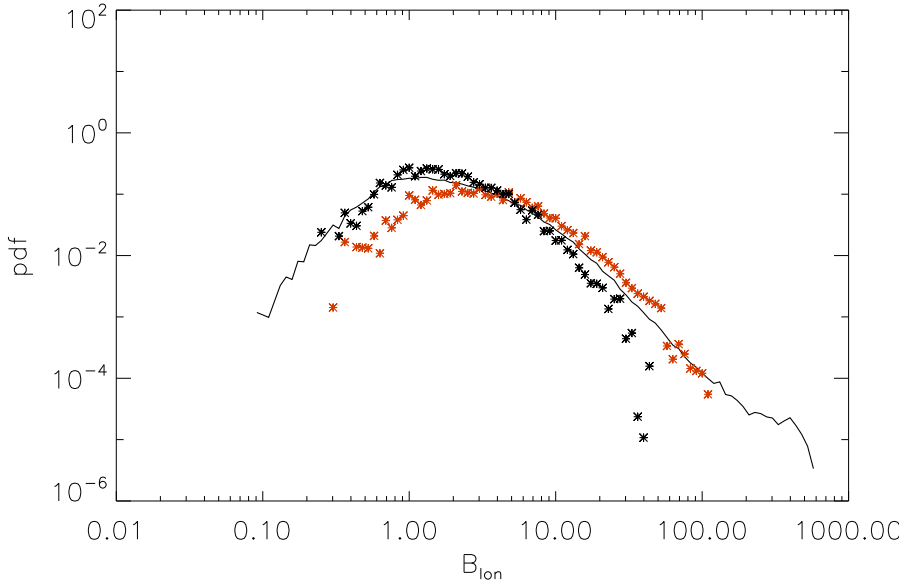
Hanle and **Zeeman** forward modeling sort of agree

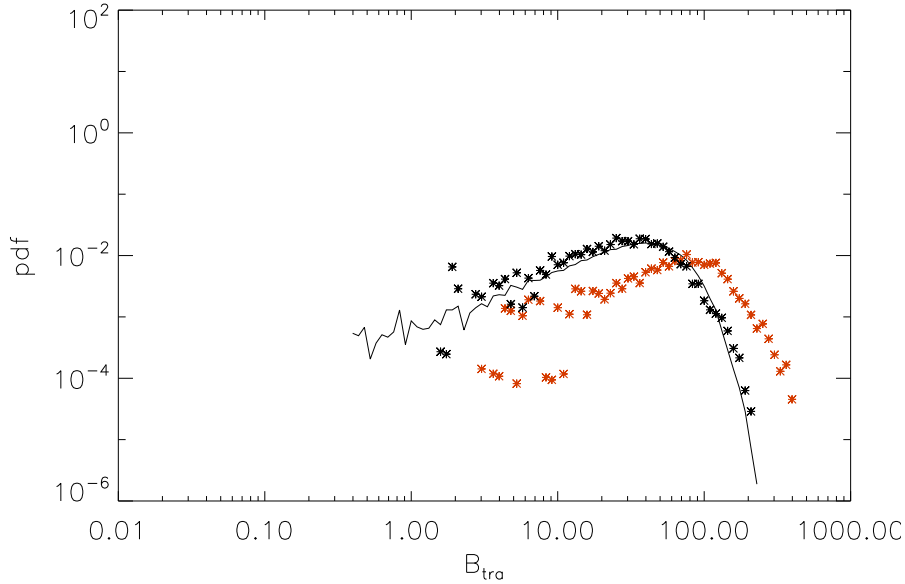


Vögler & Schüssler (2007)
MHD model-C

Sr 4607 B $\times$ 12
Shchukina & Trujillo Bueno (2011)

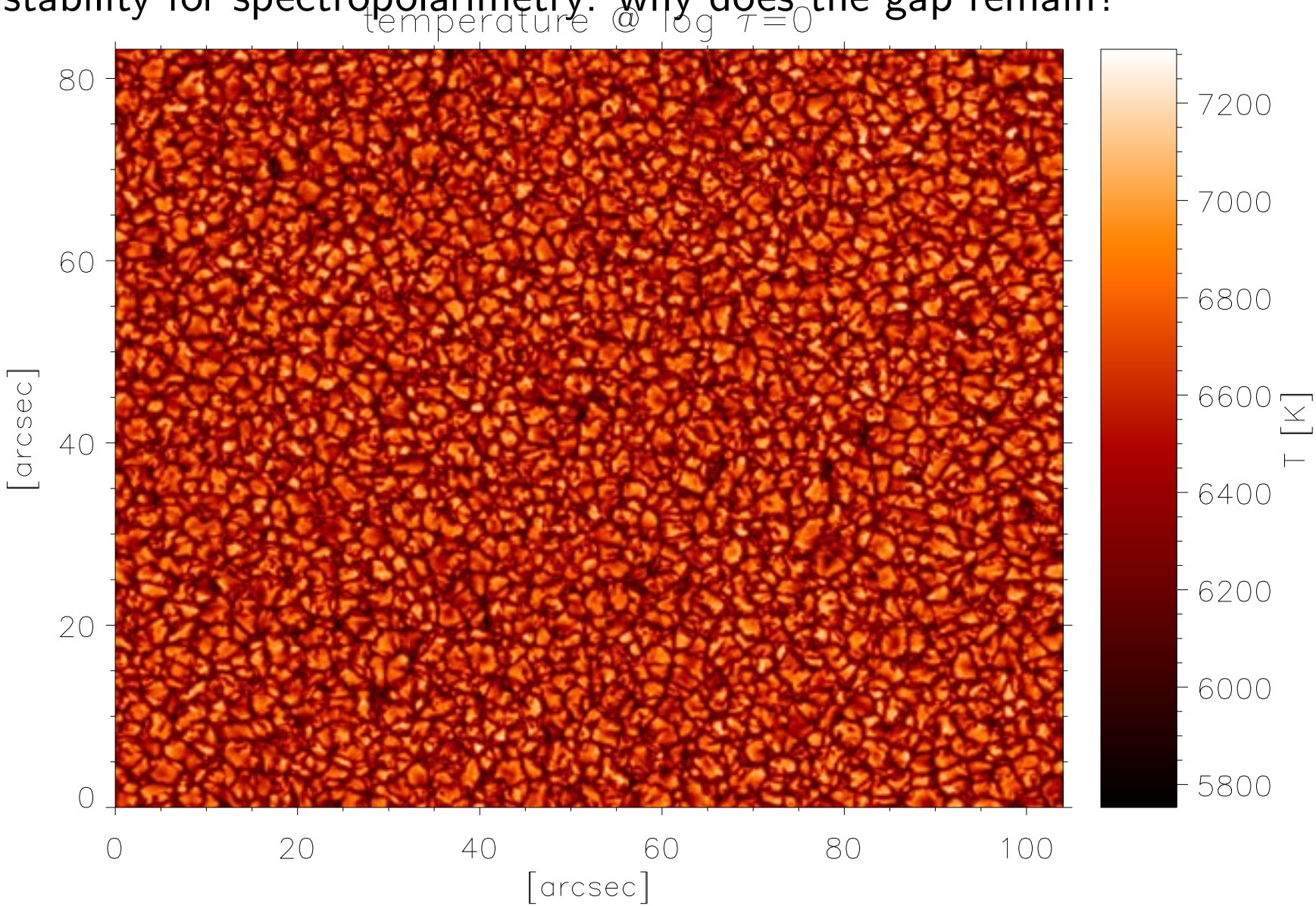
Fe 6301/2: B $\times$ 2-3
Danilovic (2010)





Hinode

Hinode SP was a real breakthrough in spatial resolution and stability for spectropolarimetry: why does the gap remain?



New reduction: Hanle-Zeeman gap appears to be closed

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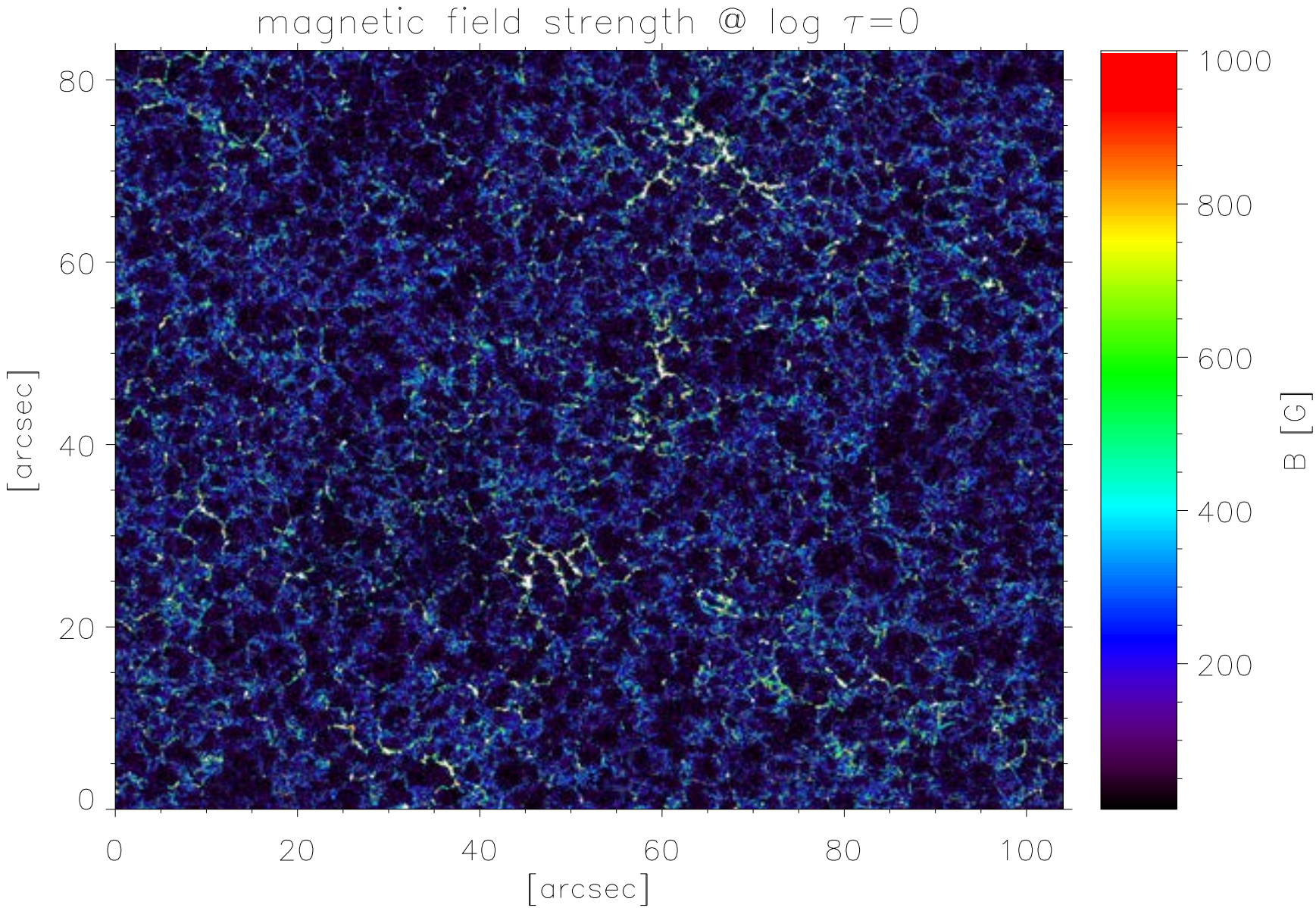
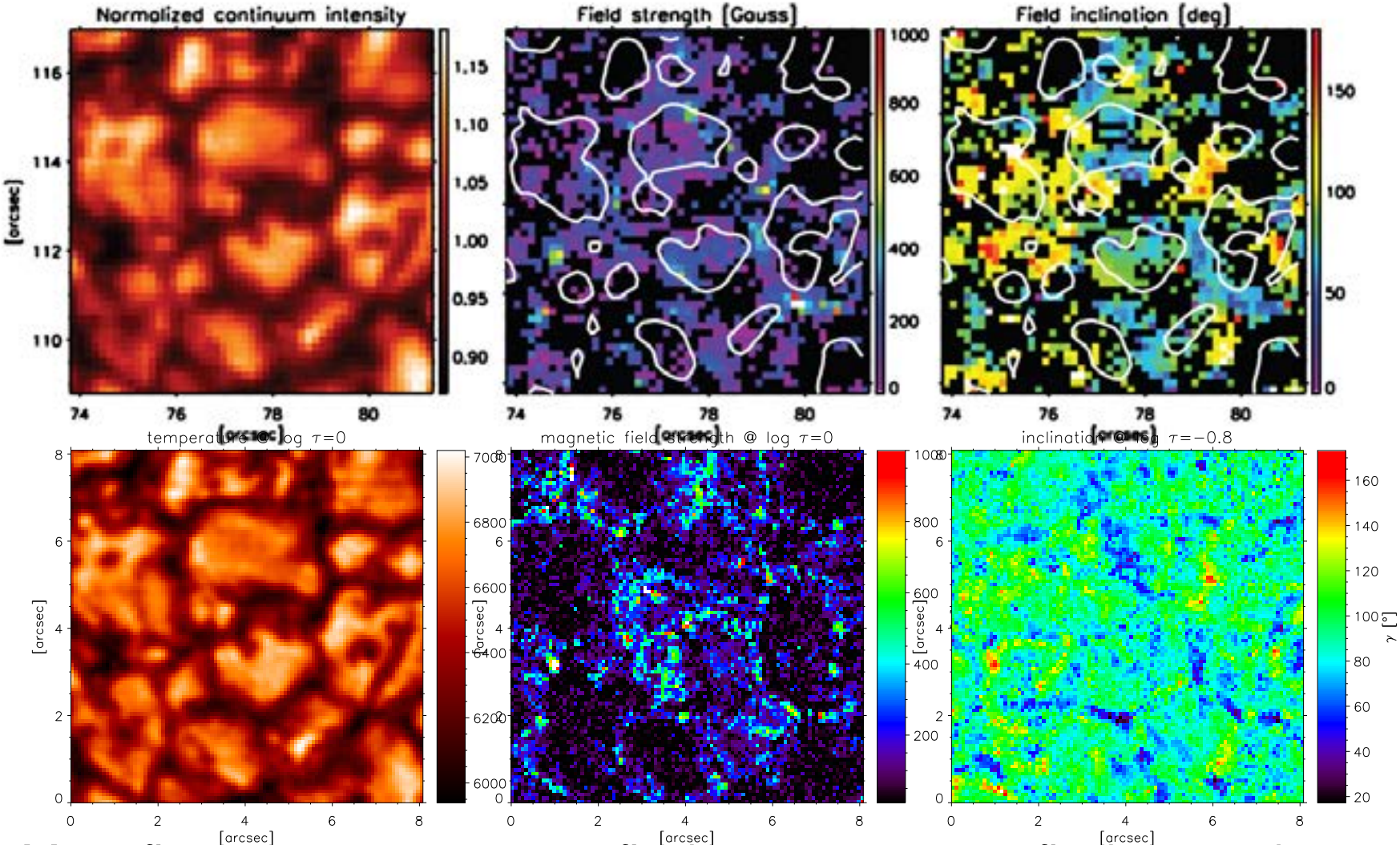
Coupled inversion

reduced cancelation = more field? More efficient = less field?



Coupled inversion

How does it compare with Orozco-Suarez et al .(2007)?



More fine structure, stronger fields, lower average field strength.

Gap not quite closed

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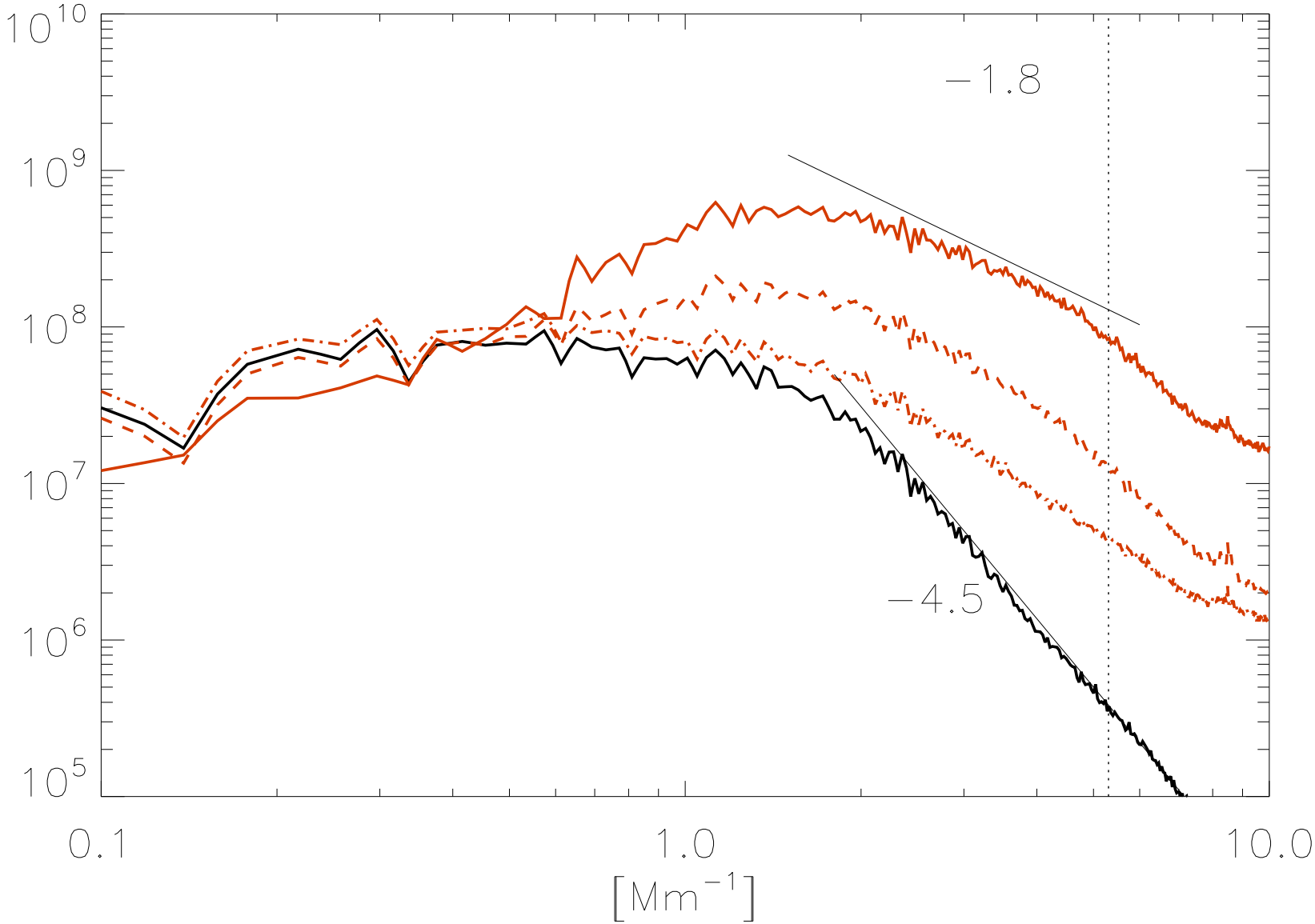
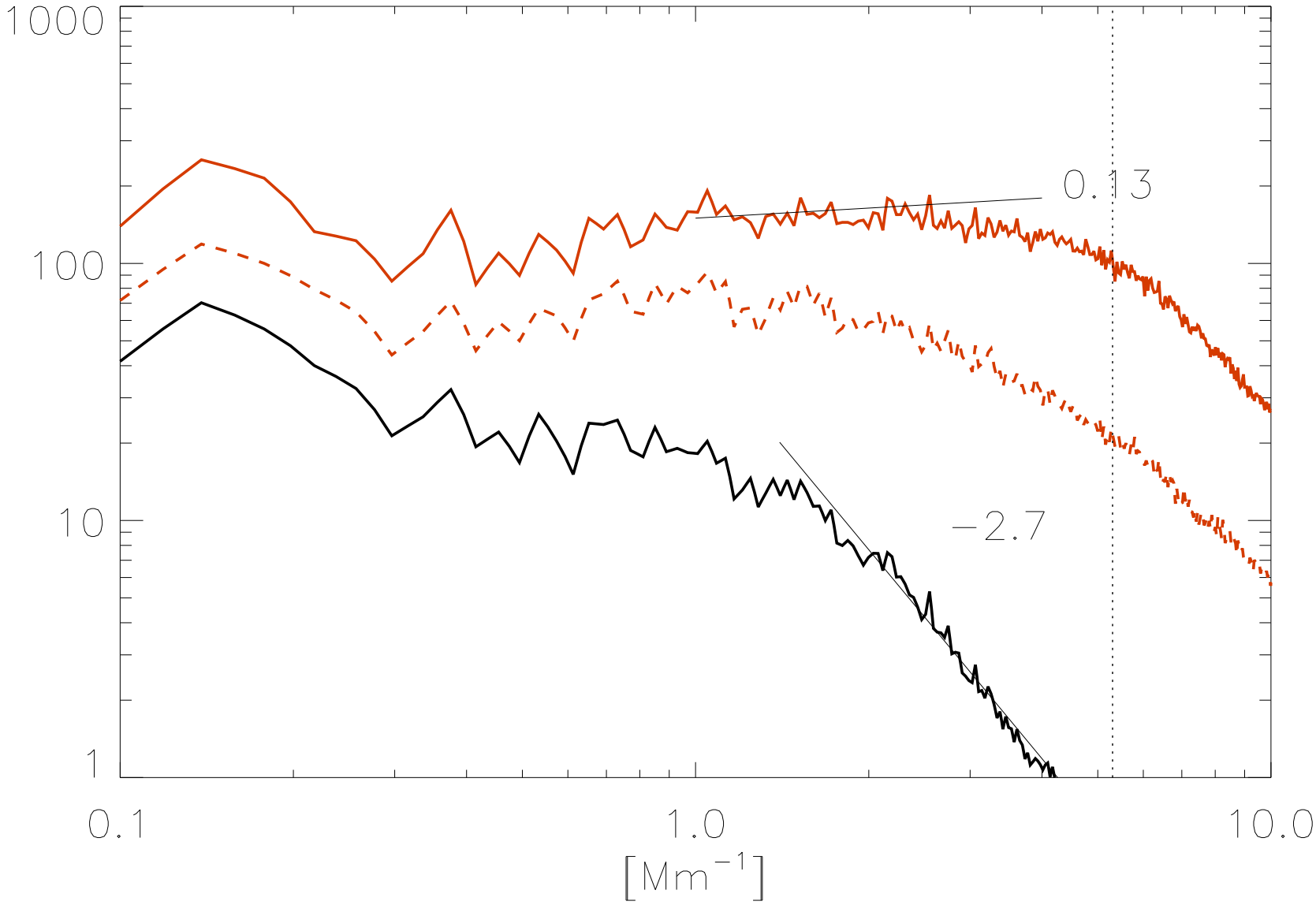
More resolution

Power spectrum V_{los} has slope close to -5/3



More unresolved fine structure

Power spectrum B_{los} almost flat: more unresolved fine structure!



Average flux density

Quiet Sun internetwork field:

- New Zeeman results give $\langle B \rangle$=130G at $\tau = 1$
- $\langle B \rangle$ $\sim$90G(?) at $\tau = 0.1 \longrightarrow$ compatible with MHD?
- How much flux can still be missing?
- Hanle effect in Sr4607 gives 130G at 300km
- How accurate is the Sr4607 result?
- Agreement within reach?

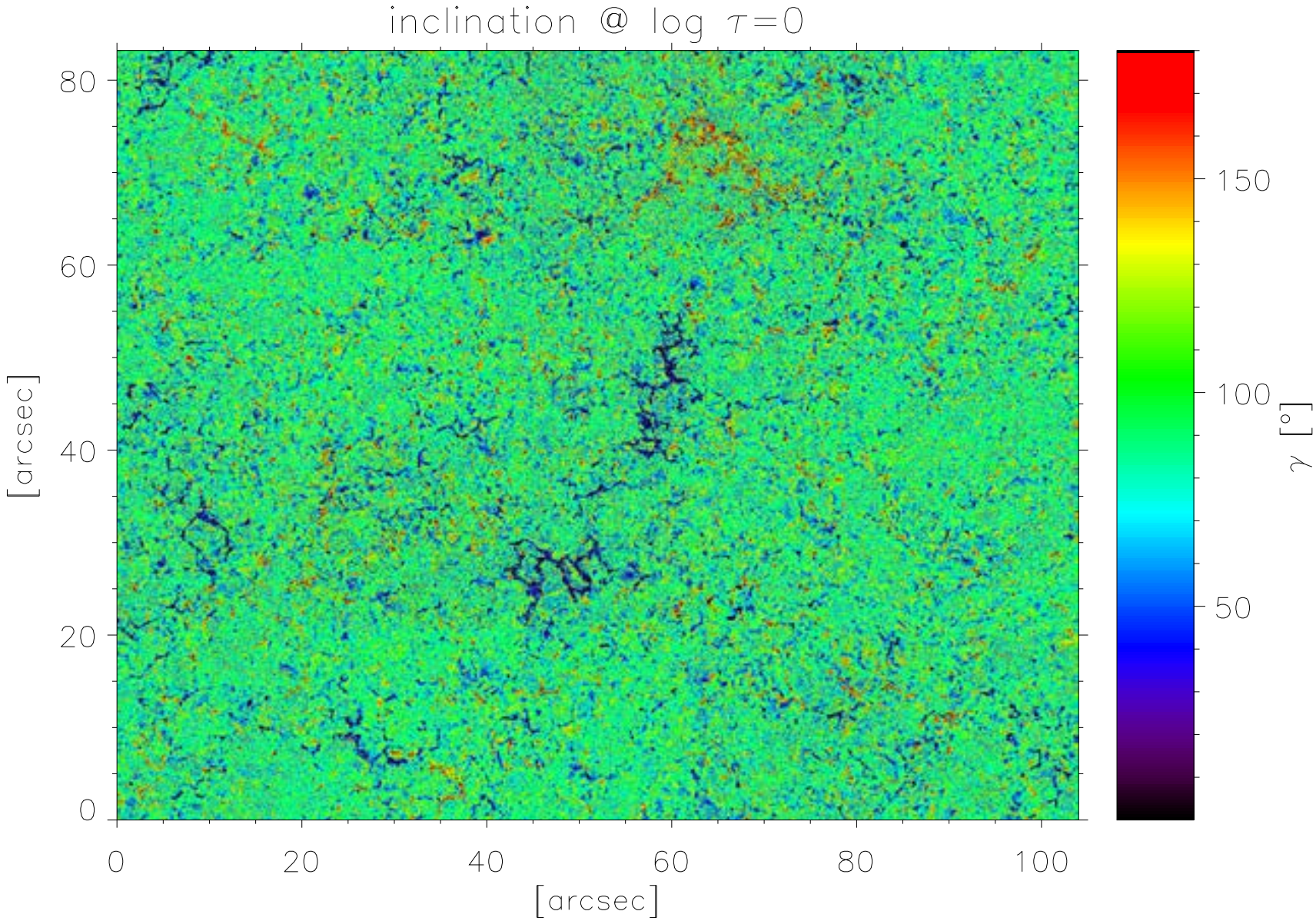
More discussions ahead

Field Orientation

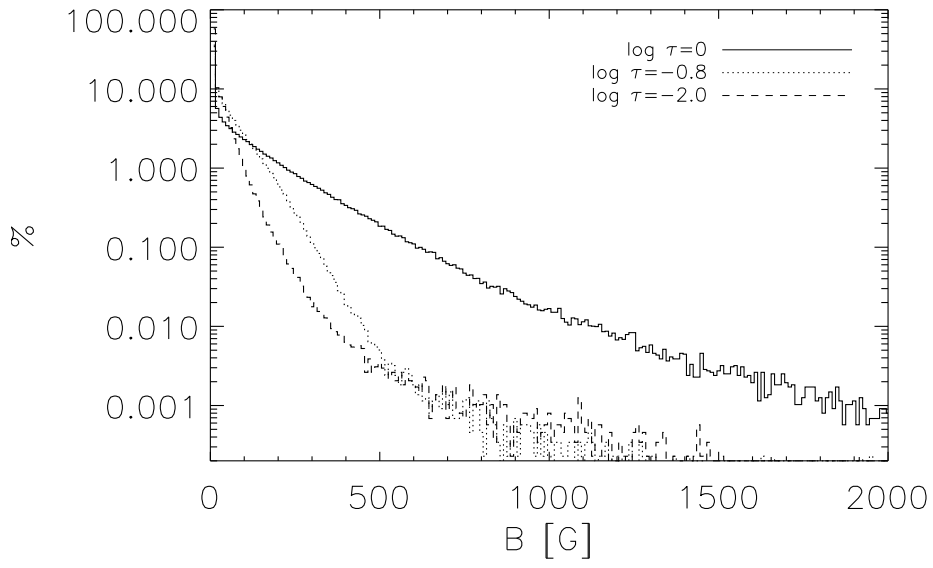
- Stenflo (1982): limits on horizontal QS fields
- Lites et al. (1996): horizontal IN fields at arcsec scale (their spatial resolution), lifetime of minutes (granulation lifetime).
- Meunier et al. (1998): CLV of IR lines: IN composed of some flux in stronger, more vertical fields and more flux in weaker, more horizontal fields.
- Orozco et al. (2007): SP: IN fields show peak in inclination distribution at 90°
- Lites et al. (2008): SP: 5 times more flux in horizontal field than in vertical field component.
- Stenflo (2010): SP: vertical strong field + isotropic weak field
- Orozco Suarez & Bellot Rubio. (2012): SP: sea of higly inclined field.

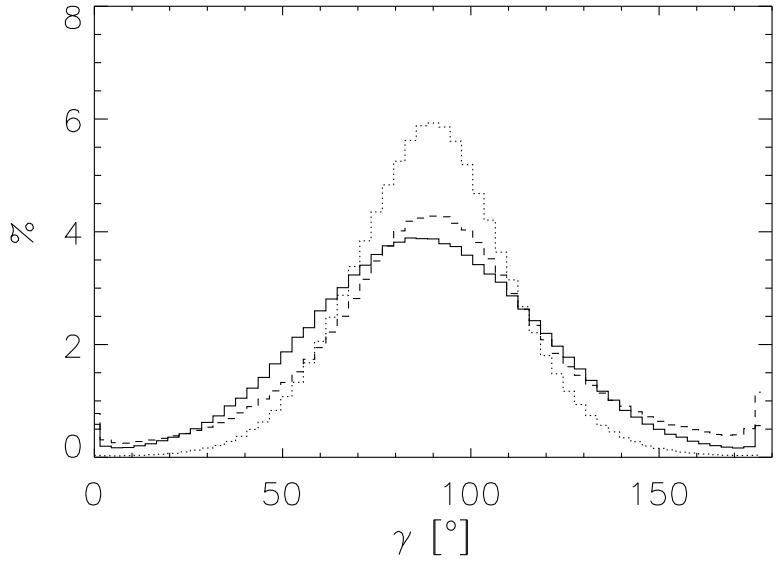
Coupled inversions

Strong fields clearly mostly vertical



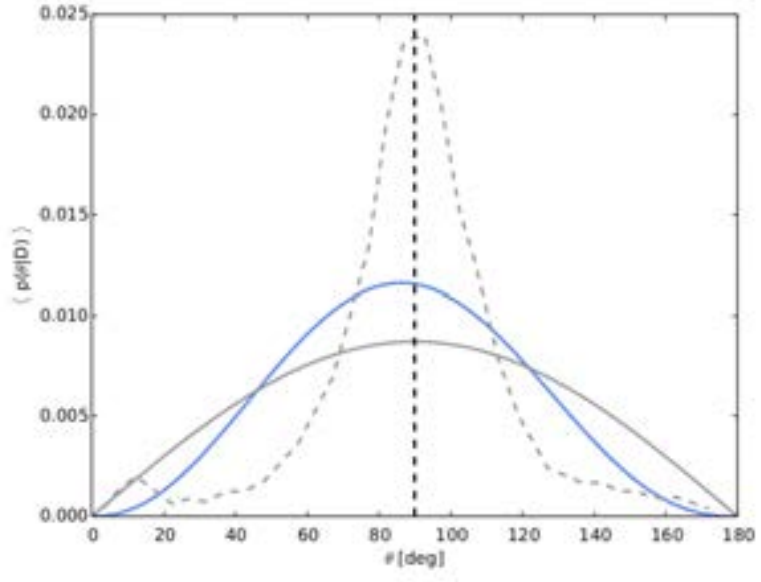
Horizontal or quasi-isotropic?





Possibly!

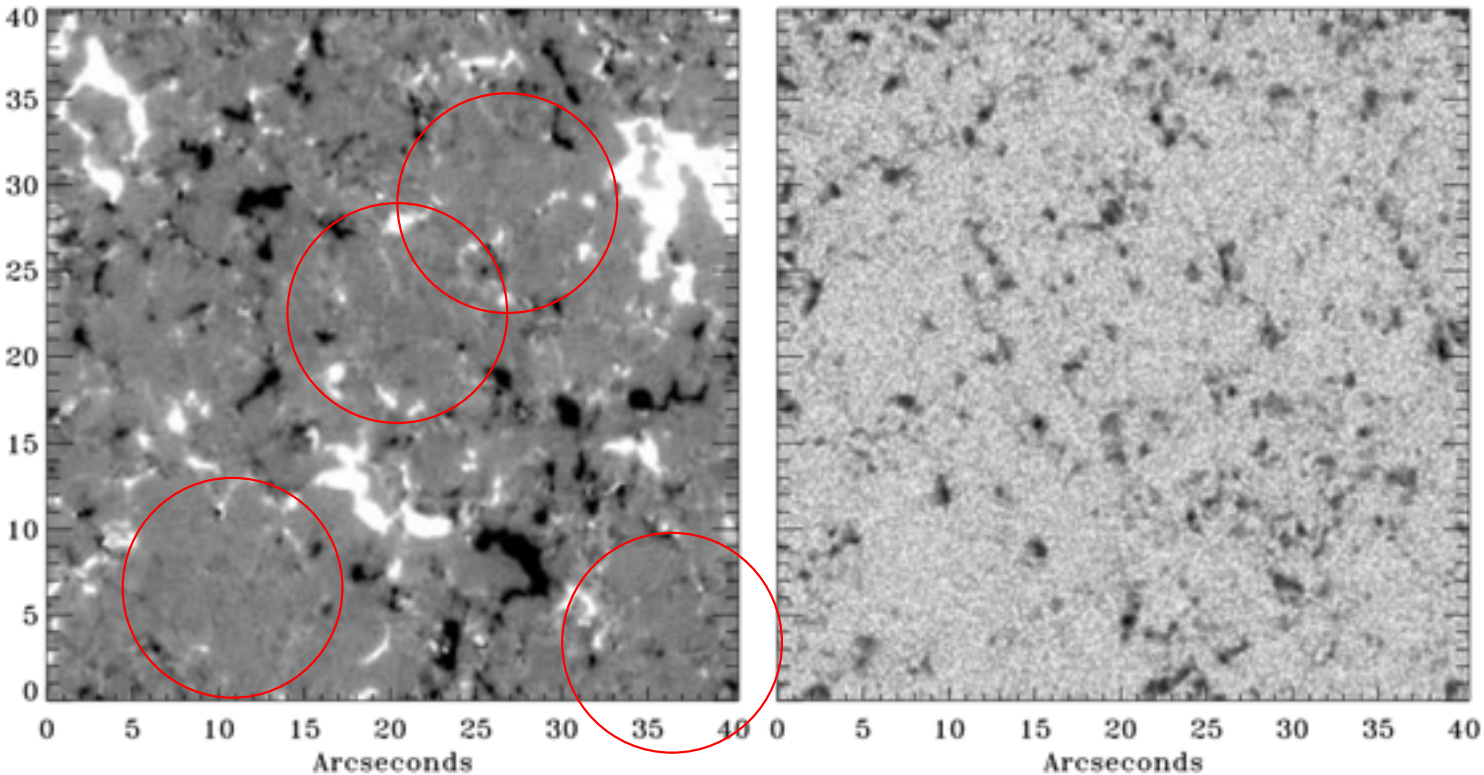
Asensio Ramos & Martinez Gonzalez (2014) compared to isotropic and Bellot Rubio & Orozco Suarez (2012)



Spatial Distribution

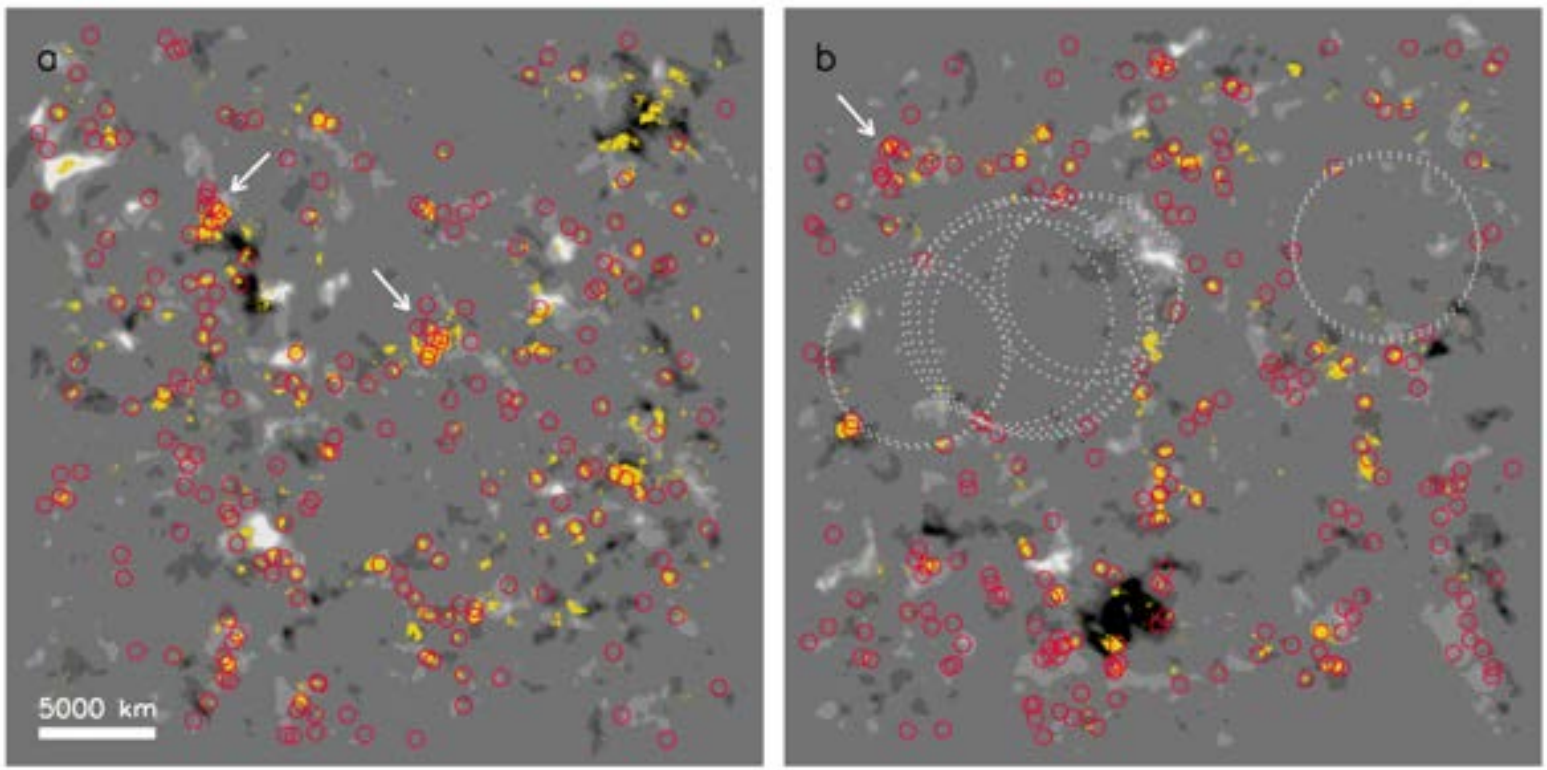
Are there characteristic scales of IN field?

Lites et al. (2008) hint of areas with low flux



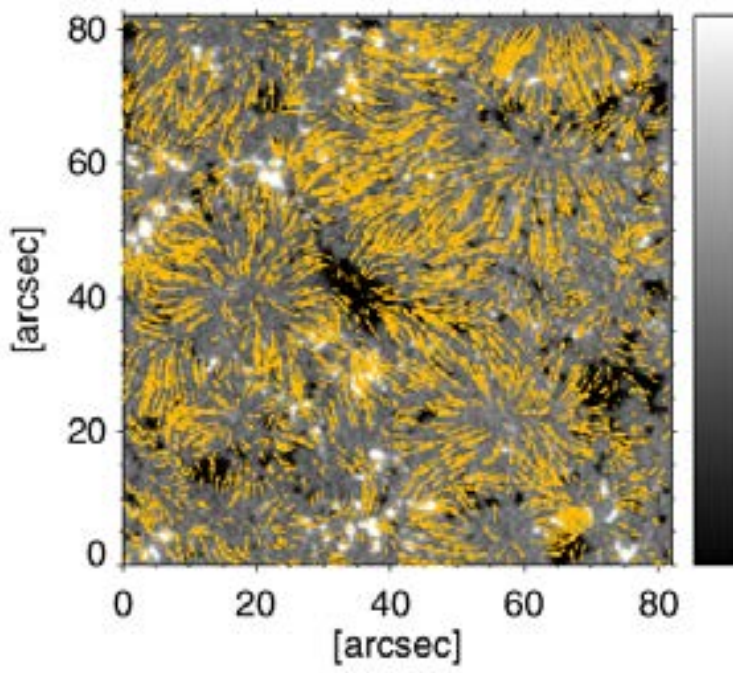
Dead-calm regions

Martinez Gonzalez (2012): SUNRISE/IMAX: Large ($> 10''$) "dead calm" regions: 5250 line "sees" different field (Danilovic in prep.)

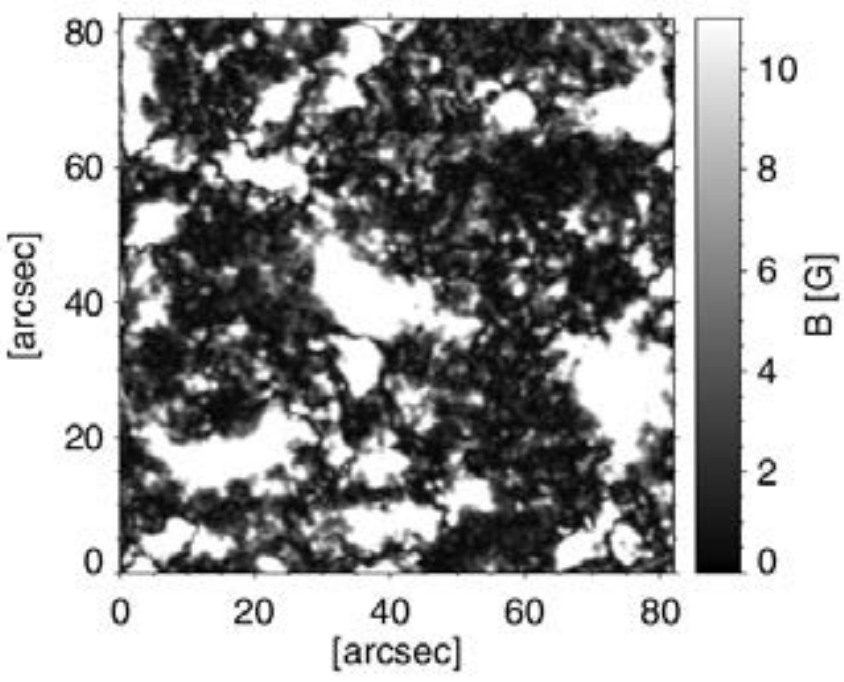


Dead-calm regions

Stangalini (2014): LCT on SOT/NFI: supergranular centers exhibit flux emergence deficit



(a) Horizontal velocity field

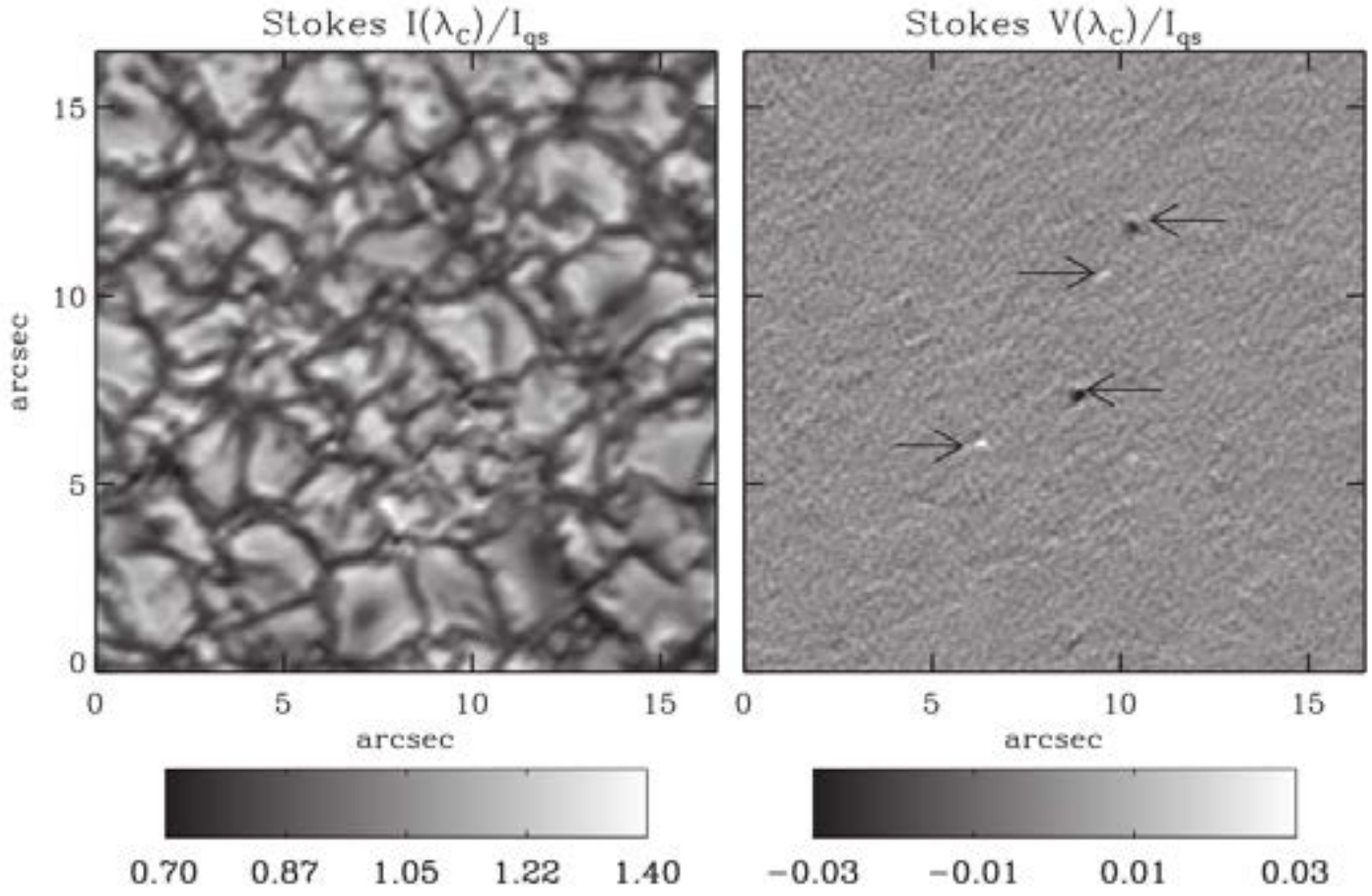


(c) Deep magnetogram

spatial scale seems about right

Dynamics: QS "jets"

SUNRISE/IMAX: Borrero et al. (2010): transient upflows (81s lifetime) with single lobed Stokes V profiles shifted to continuum

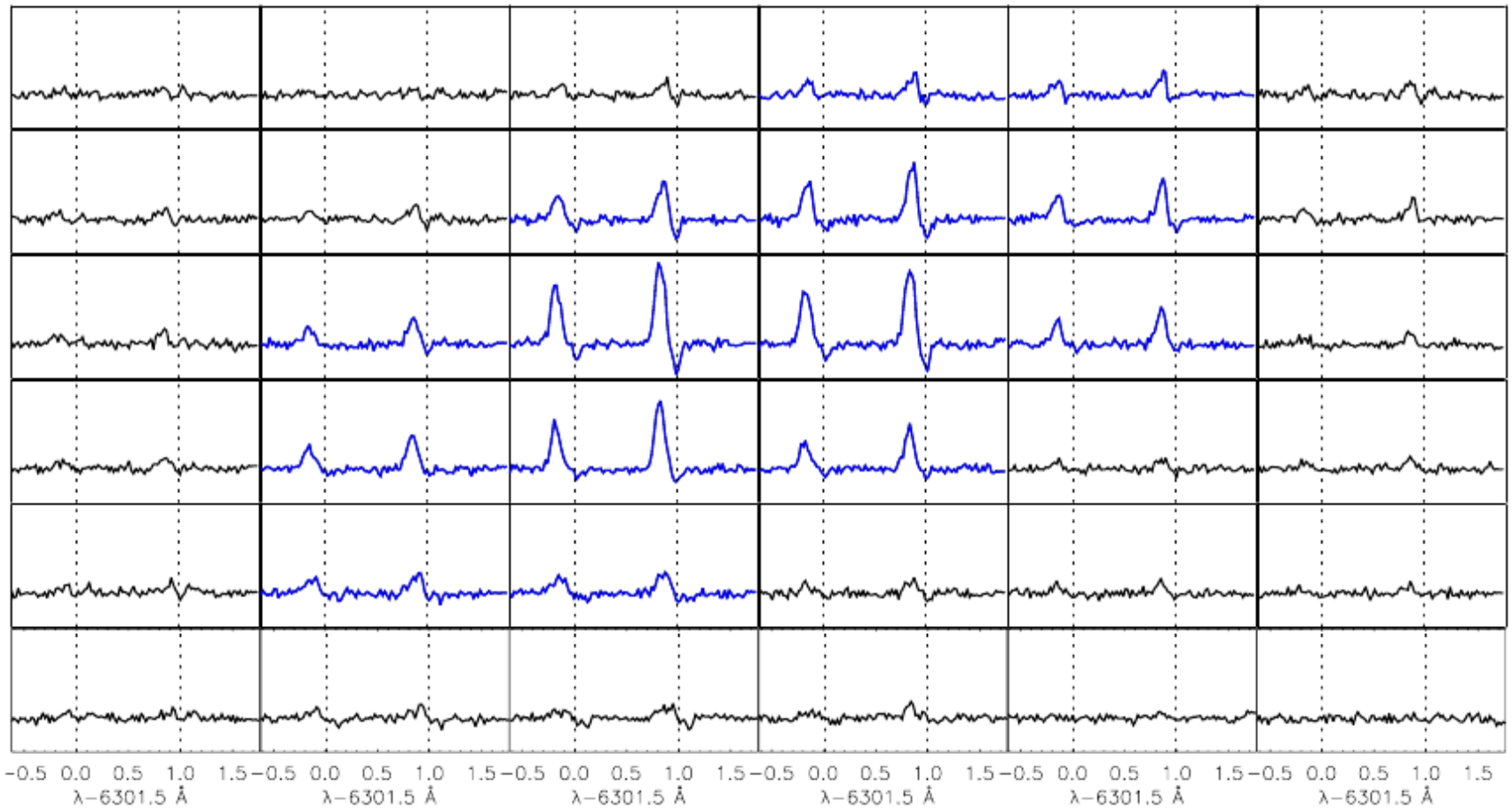


Reconnection jets in the QS?

QS loops

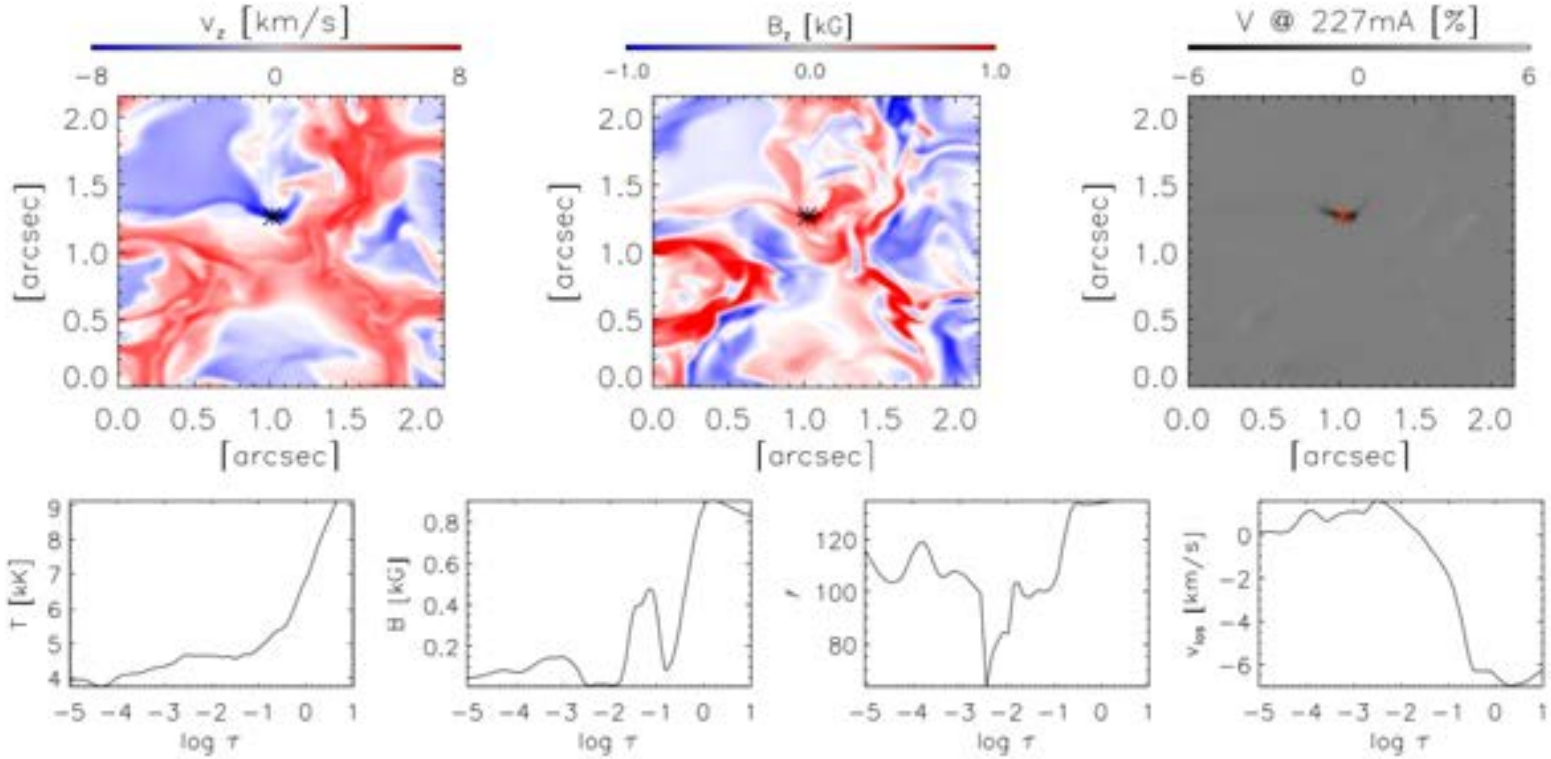
Follow-up using Hinode/SP rapid scans 36s cadence

Quintero Noda et al. (2014): $\longrightarrow$ emerging loops



QS loops

Danilovic et al. (2014): MHD simulation compatibel with boyant emerging flux



Only one event found

QS downflows

More recently:

Hinode/SP rapid scans
36s cadence

Quintero Noda et al. (2014):
hot upper atmosphere
downflow lifetime: $\sim$360s
$\longrightarrow$ spicules?