Quiet-Sun Observations

A 2-D inversion attempt

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Scan of quiet sun region (2015-Sep-17)

- FFT rebinned: 0.″135 pixelsize

→ 0.″20 pixelsize (seeing limited: 0.″40)

- noise level reduction: $4 \cdot 10^{-4}$ I_C

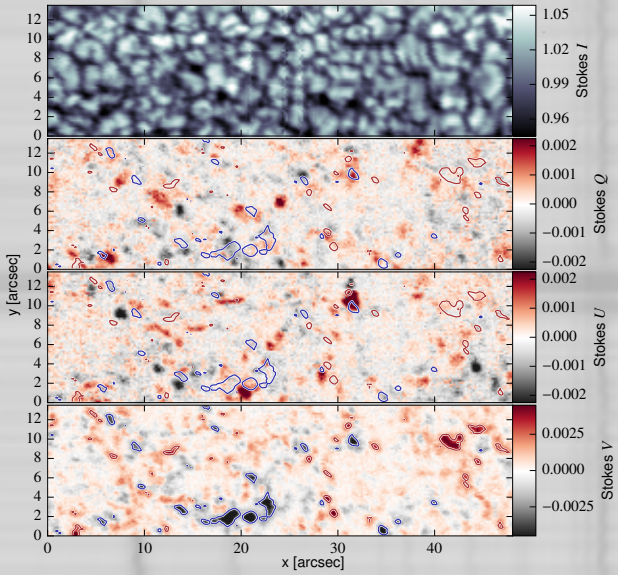
→ $2.7 \cdot 10^{-4}$ I_C

→ no loss in spatial resolution

- spectral binning

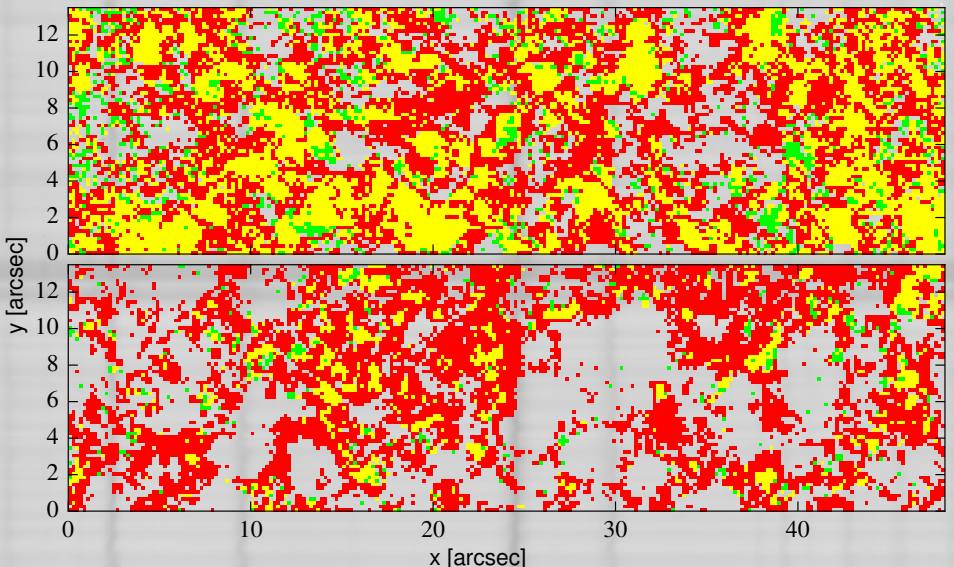
→ $\times 2$ (oversampling)

→ $2.1 \cdot 10^{-4}$ I_C



Comparison: GRIS vs. SOT/SP: LP/CP Coverage

$V \geq 3\sigma$ $Q, U \geq 3\sigma$ $Q, U, V \geq 3\sigma$



GREGOR/GRIS
4.8 s, 0.″40, $2 \cdot 10^{-4}$

Hinode SOT/SP
12.8 s, 0.″40, $7 \cdot 10^{-4}$

Stokes signal levels

Comparison GRIS ↔ Hinode SOT/SP

σ-level	GRIS [%]		LP and CP	LP or CP	SOT/SP [%]		LP and CP	LP or CP
	LP	CP			LP	CP		
3σ	39.7	73.0	33.1	79.7	9.8	49.3	7.7	51.4
4σ	18.4	57.0	13.9	61.5	4.2	37.1	3.1	38.2
5σ	9.2	44.2	6.2	47.2	2.1	28.5	1.5	29.1

Extracting information from the Stokes spectra

Stokes profile diagnostics
Lagg et al. (2016)

magnetic line ratio, LP/CP

- based directly on Stokes profiles
- no complex analysis involved
- obtain B-strength directly (avoid FF problems)
- only coarse B determination
- very limited inclination information

1D-Inversions
Martínez González et al. (2016)

ME-type, SIR, SPINOR

- accurate B, γ, ϕ
- height-information
- provides PDFs
- Zeeman-bias $B_{||} \longleftrightarrow B_{\perp}$
- FF / straylight factor required

Simple diagnostic techniques: MLR - field strength

Magnetic Line Ratio (Solanki et al., 1992)

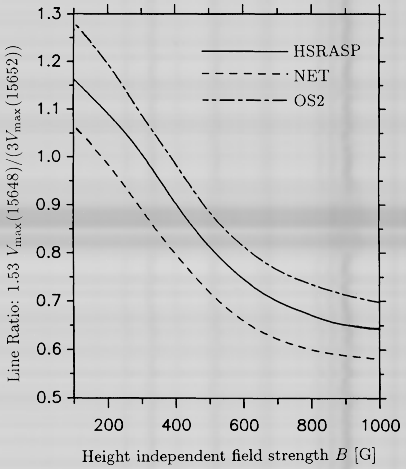
$$\mathrm{MLR} = \frac{g_{\mathrm{eff}}(15652)\, V_{\mathrm{max}}(15648)}{g(15648)\, V_{\mathrm{max}}(15652)}$$

Requirements:

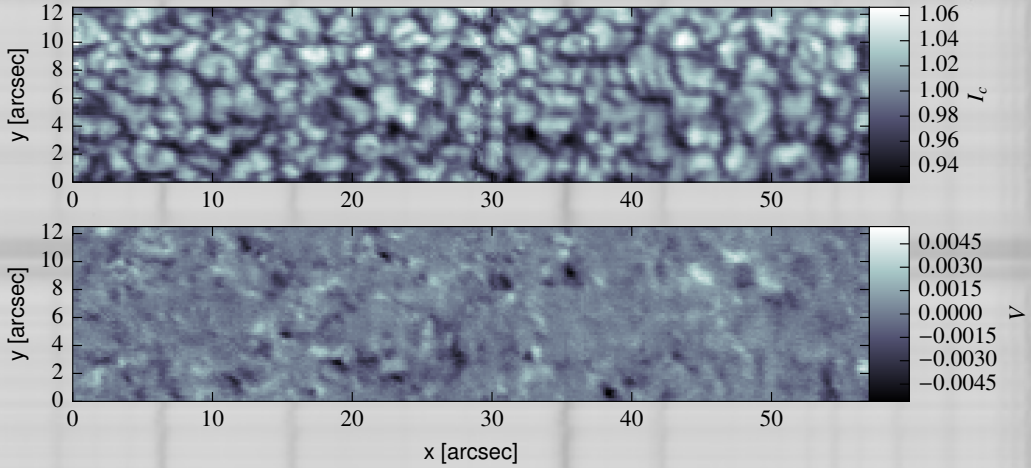
- spectral lines identical except for Landé factor
- 2 distinct components:
  (1) magnetized, (2) field-free
- small gradients in $\log \tau$

→ not fulfilled for Fe I 1.56 line pair

→ BUT: similar formation height, narrow formation height range, similar thermal properties



Different MLR regions - Where?



MLR≈1.2, small V_{max} (hG) | MLR≈1.2, large V_{max} (hG) | MLR≈0.6, small V_{max} (kG) | MLR≈0.6, large V_{max} (kG)

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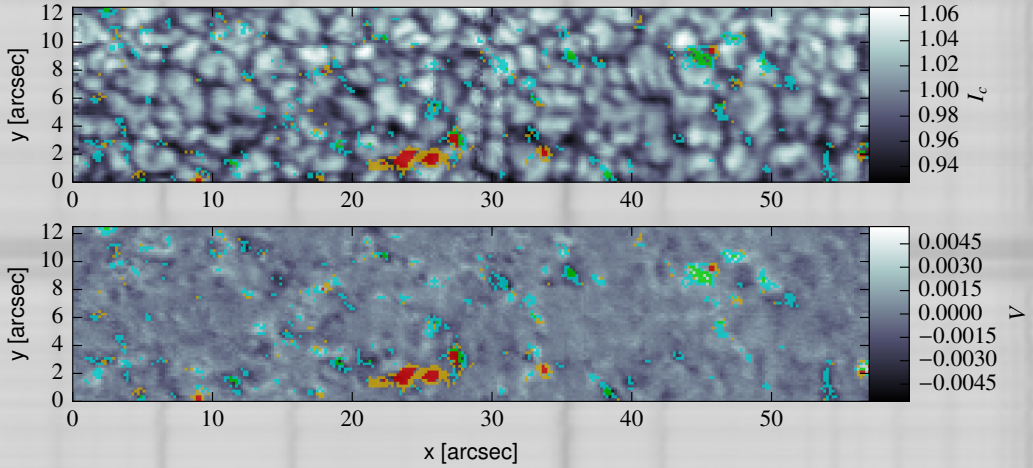

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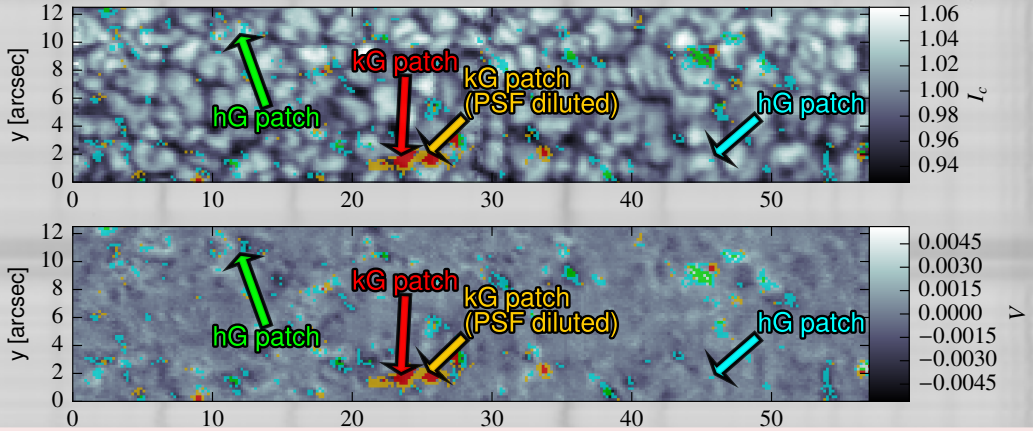
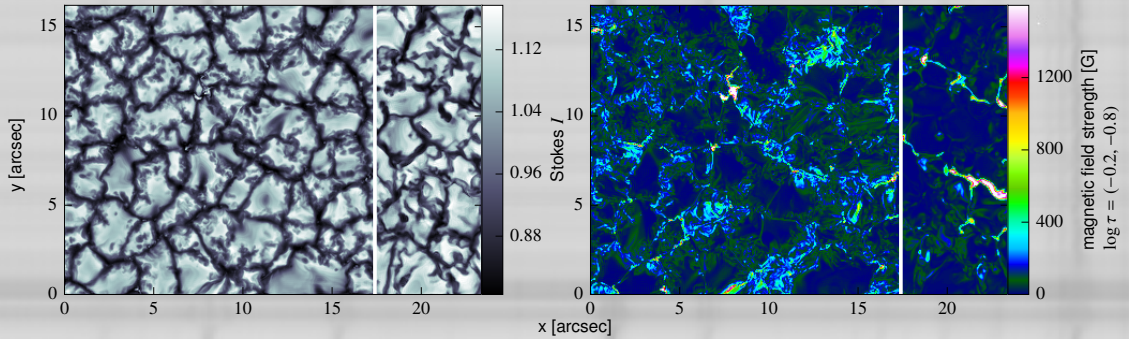


some kG patches (red); surrounded by yellow halo; ubiquitous weak fields (green & blue)

MLR≈1.2, small V_{max} (hG) | MLR≈1.2, large V_{max} (hG) | MLR≈0.6, small V_{max} (kG) | MLR≈0.6, large V_{max} (kG)

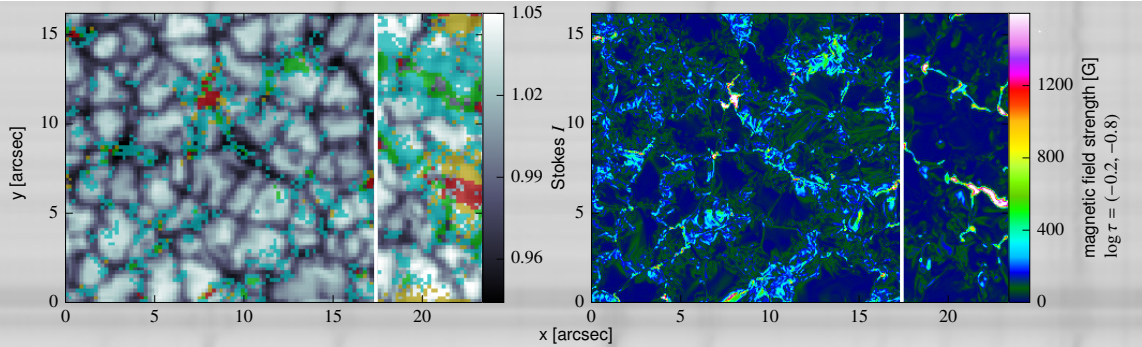
Test using MHD Quiet Sun simulations (SSD+IMaX run)



MHD simulations: SSD+IMaX run

- Rempel (2014): O16bM
- Riethmüller et al. (2016)

Test using MHD Quiet Sun simulations (SSD+IMaX run)



spatial degrading

- GREGOR-PSF + 0.25″ Gaussian + Lorentzian wings

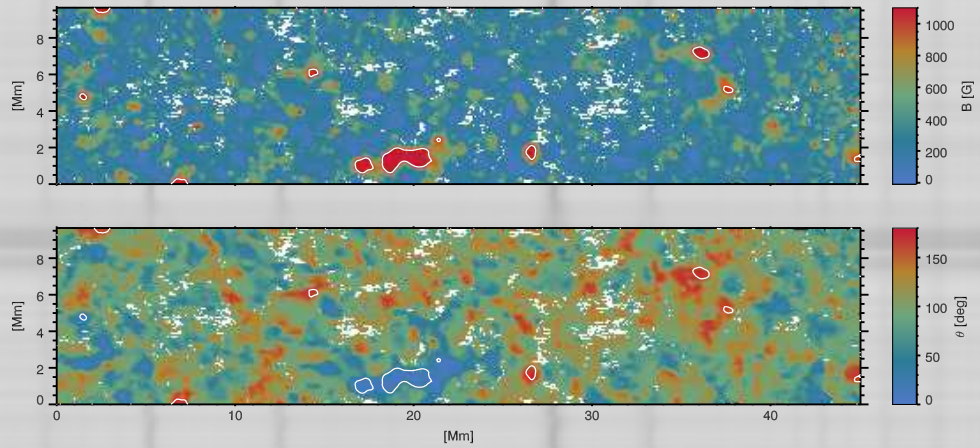
→ match contrast, resolution, I_c histogram

spectral degrading

- 12% straylight
- 150 mÅ Gauss

MLR≈1.2, small V_{max} (hG) MLR≈1.2, large V_{max} (hG) MLR≈0.6, small V_{max} (kG) MLR≈0.6, large V_{max} (kG)

Martínez González et al. (2016)



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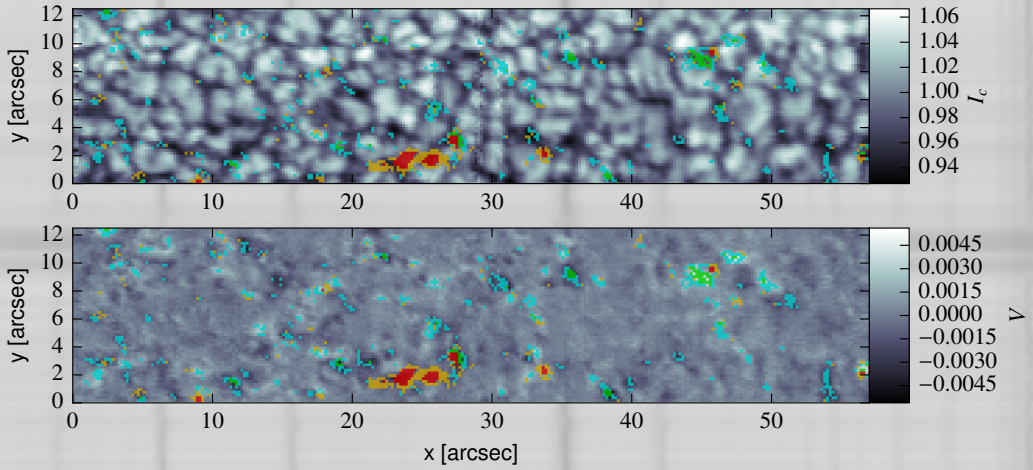

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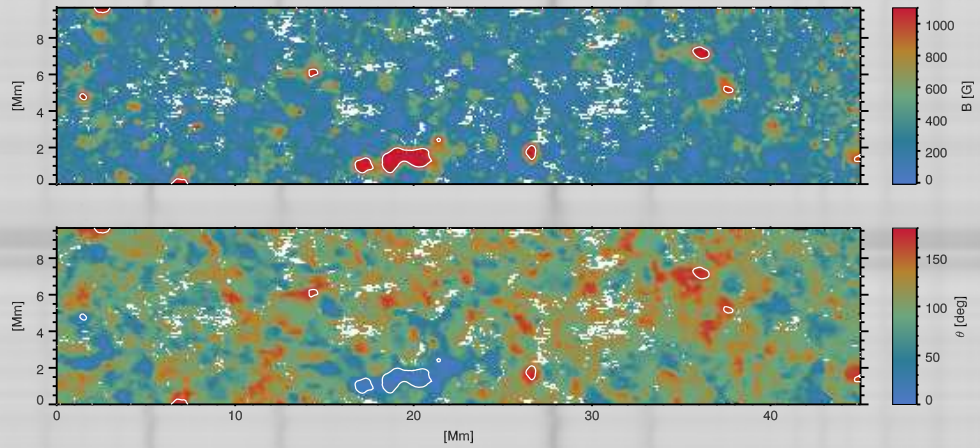
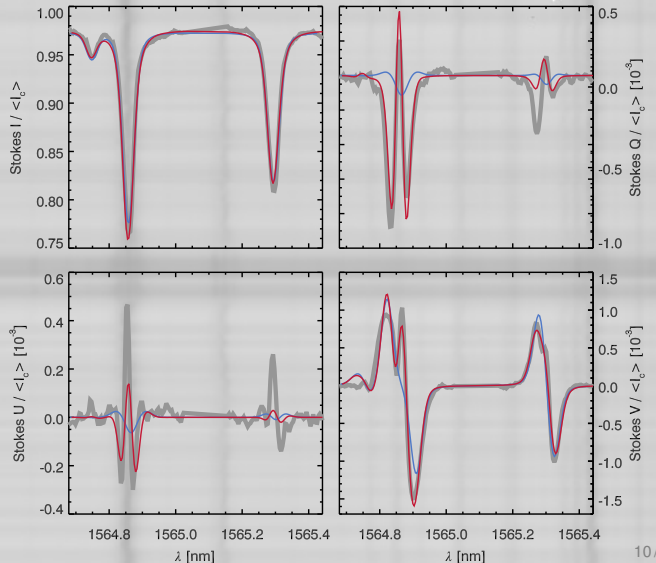


Martínez González et al. (2016) - unresolved magnetic fine structure

Multi-lobed profiles



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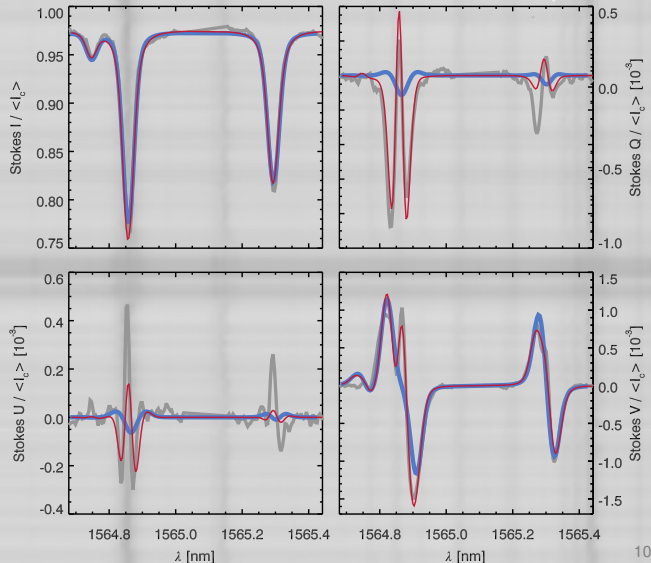
Multi-lobed profiles

1C-model + unpolarized straylight

→ unable to reproduce observation



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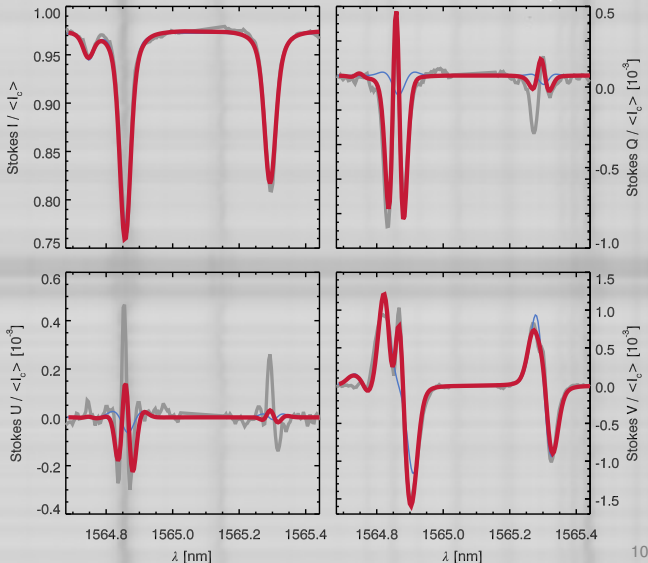
Multi-lobed profiles

1C-model + unpolarized straylight

→ unable to reproduce observation

2 magn. comp. + unpolarized straylight

→ decent fit



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Multi-lobed profiles

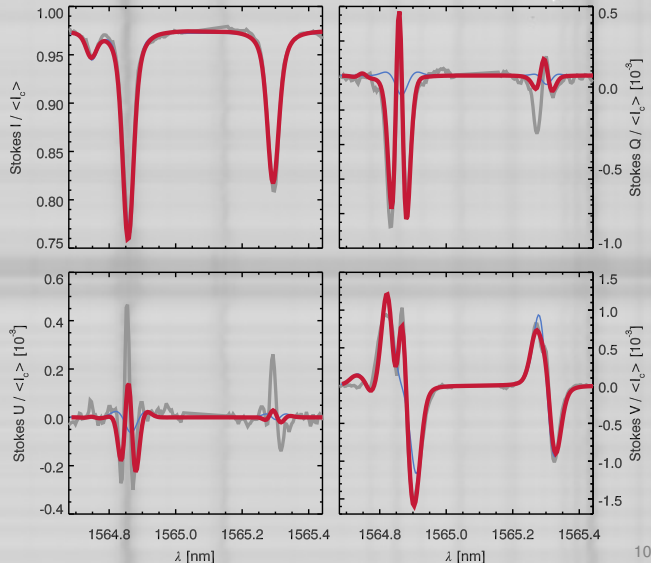
1C-model + unpolarized straylight

→ unable to reproduce observation

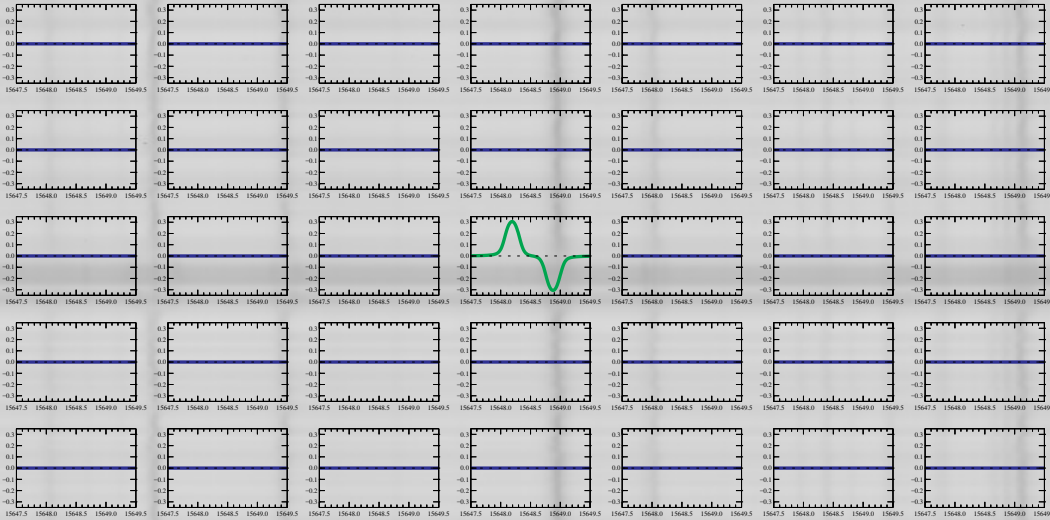
2 magn. comp. + unpolarized straylight

→ decent fit

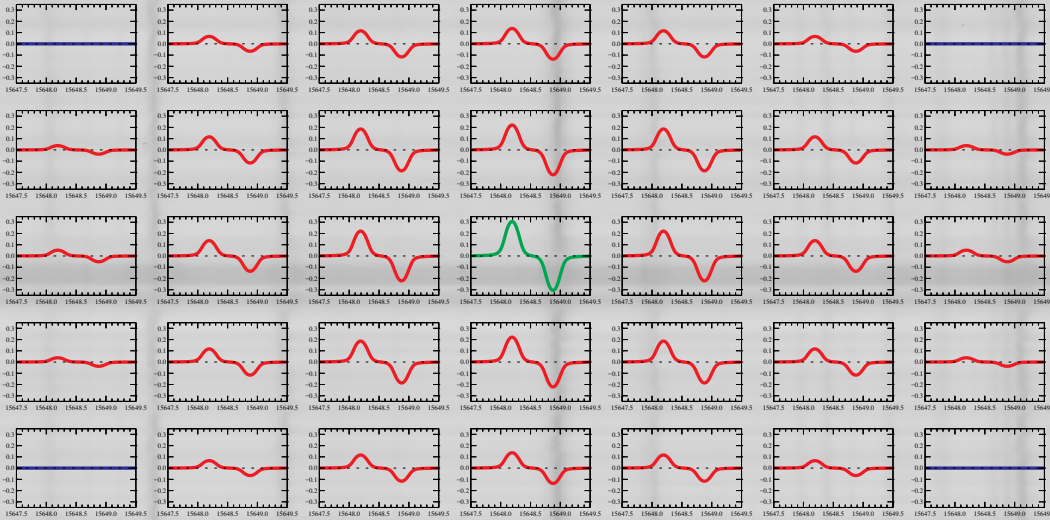
- Is this unresolved finestructure?
- Simpler model possible?



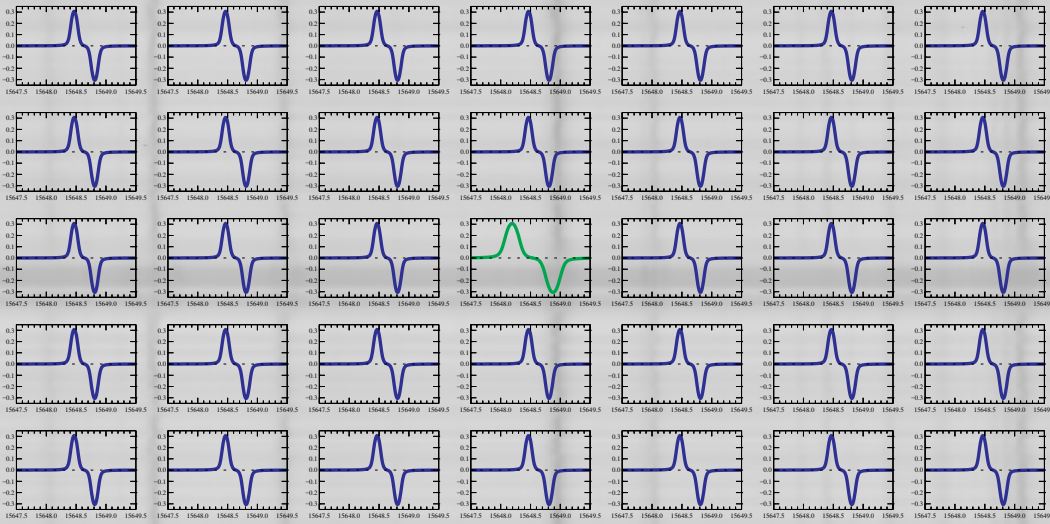
PSF influence - magnetic pixel in QS - no PSF



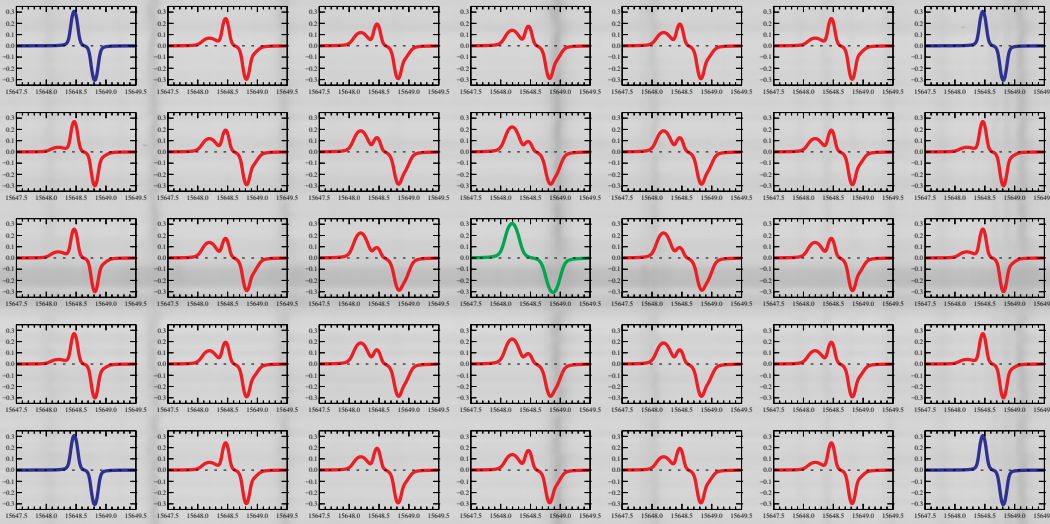
PSF influence - magnetic pixel in QS - with PSF



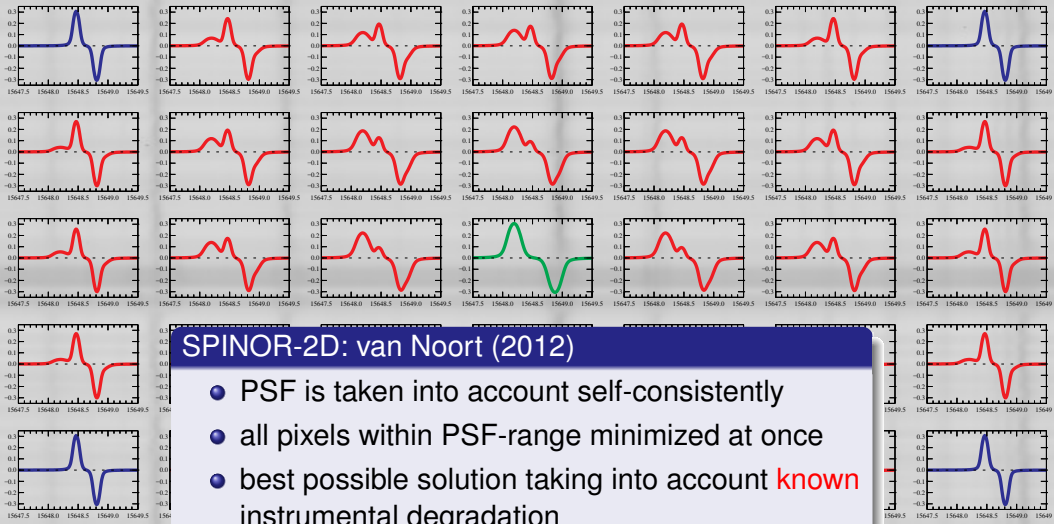
PSF influence - magnetic pixel in weak *B* environment - no PSF



PSF influence - magnetic pixel in weak *B* environment - with PSF



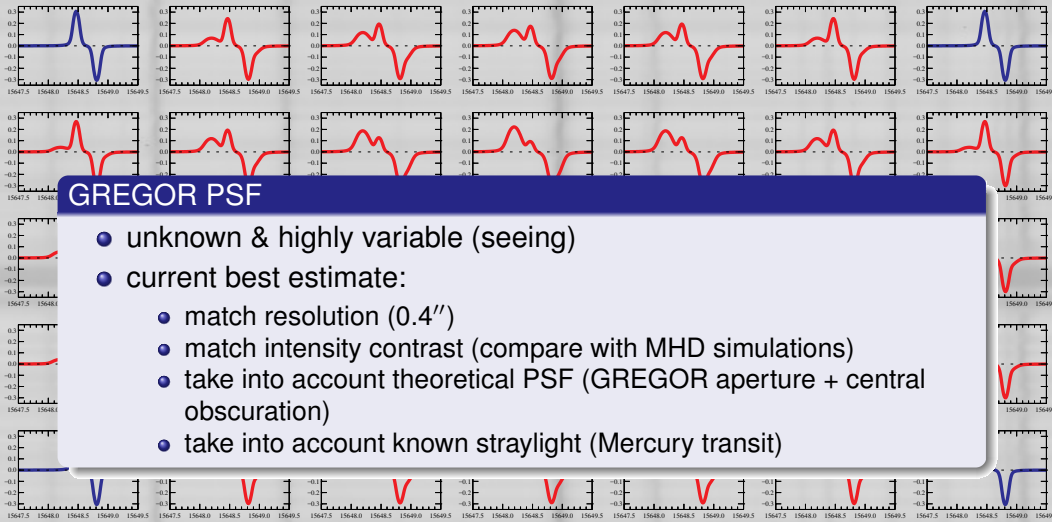
2D (spatially coupled) inversions



SPINOR-2D: van Noort (2012)

- PSF is taken into account self-consistently
- all pixels within PSF-range minimized at once
- best possible solution taking into account known instrumental degradation

PSF@GREGOR

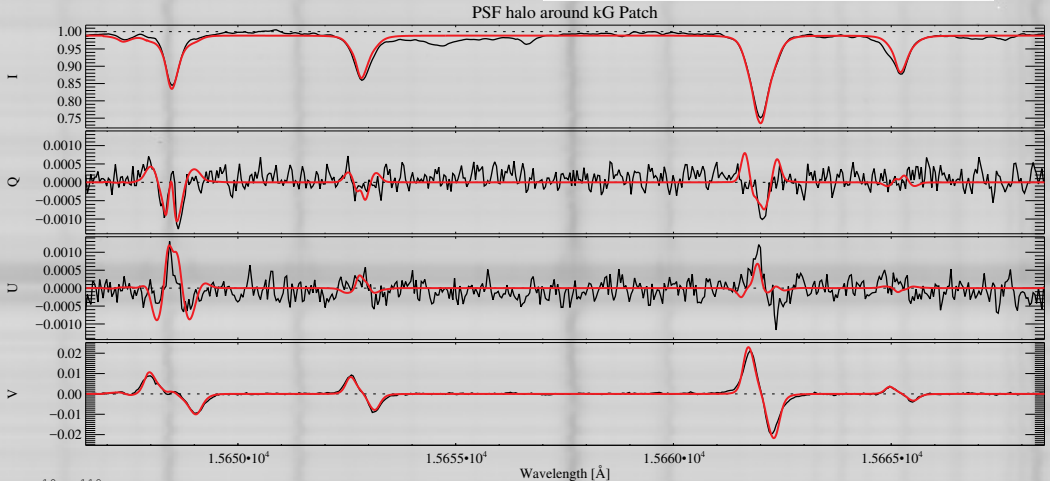


GREGOR PSF

- unknown & highly variable (seeing)
- current best estimate:
  - match resolution (0.4″)
  - match intensity contrast (compare with MHD simulations)
  - take into account theoretical PSF (GREGOR aperture + central obscuration)
  - take into account known straylight (Mercury transit)

Stokes profile - kG patch

$\log\tau = -0.8$: $B = 1320\,\mathrm{G}$, $\gamma = 27^\circ$

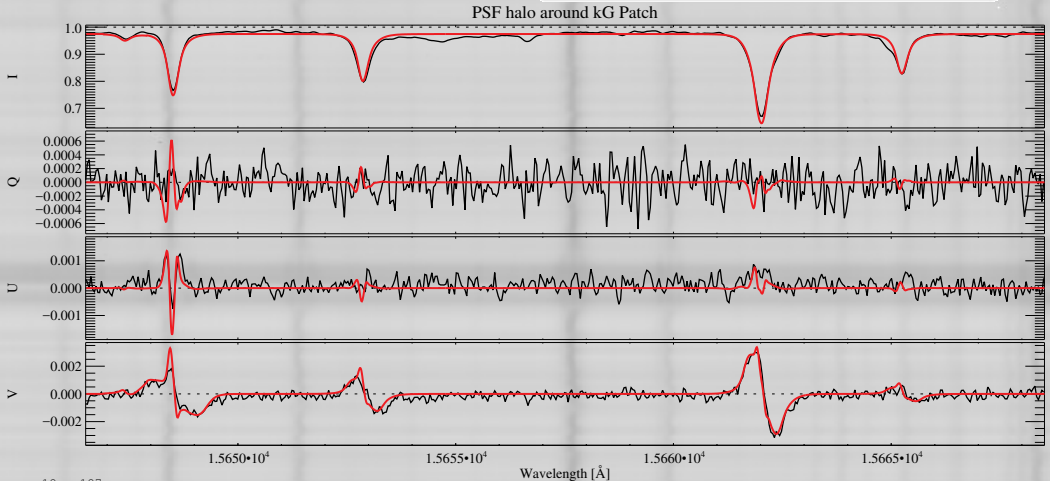


x=10,y=119

TEMPE (C1,LT-2.00) =	5508.136	TEMPE (C1,LT-0.80) =	5994.528	TEMPE (C1,LT 0.00) =	6605.778
BFIEL (C1,LT-2.00) =	1737.057	BFIEL (C1,LT-0.80) =	1323.713	BFIEL (C1,LT 0.00) =	1.000
GAMMA (C1,LT-2.00) =	30.010	GAMMA (C1,LT-0.80) =	27.782	GAMMA (C1,LT 0.00) =	162.965
AZIMU (C1,LT-2.00) =	28.989	AZIMU (C1,LT-0.80) =	-5.964	AZIMU (C1,LT 0.00) =	-94.777
VELOS (C1,LT-2.00) =	0.549	VELOS (C1,LT-0.80) =	-0.469	VELOS (C1,LT 0.00) =	0.924
VMICI (C1,LT-2.00) =	2.439	VMICI (C1,LT-0.80) =	2.732	VMICI (C1,LT 0.00) =	6.724
AINST (C0,LT 0.00) =	0.000	VINST (C0,LT 0.00) =	1.350	THETA (C0,LT 0.00) =	0.000
CHISQ (C0,LT 0.00) =	136.459				

Stokes profile - PSF halo around kG patch (1)

$\log\tau = -0.8$: $B = 30\,\mathrm{G}$, $(\gamma = 64^\circ)$

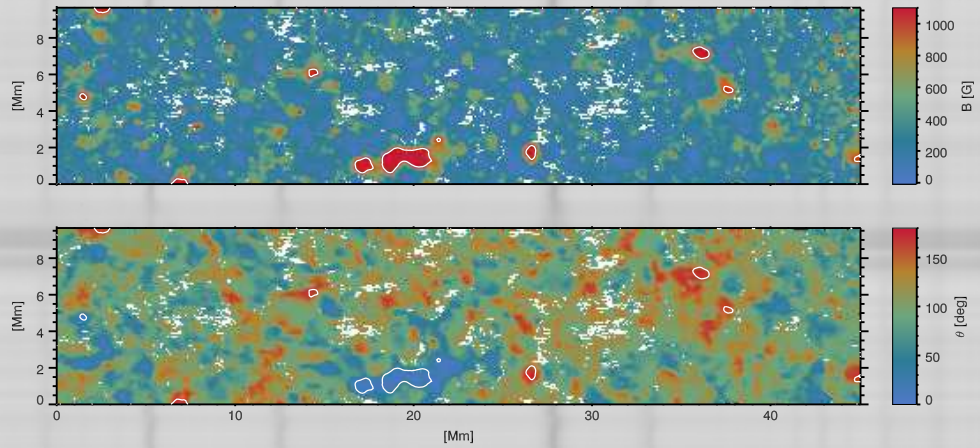


x=12,y=127

TEMPE (C1,LT-2.00) =	5197.611	TEMPE (C1,LT-0.80) =	5197.611	TEMPE (C1,LT 0.00) =	6495.994
BFIEL (C1,LT-2.00) =	238.275	BFIEL (C1,LT-0.80) =	29.986	BFIEL (C1,LT 0.00) =	1.000
GAMMA (C1,LT-2.00) =	92.592	GAMMA (C1,LT-0.80) =	64.528	GAMMA (C1,LT 0.00) =	45.608
AZIMU (C1,LT-2.00) =	59.987	AZIMU (C1,LT-0.80) =	48.618	AZIMU (C1,LT 0.00) =	46.036
VELOS (C1,LT-2.00) =	-0.964	VELOS (C1,LT-0.80) =	0.455	VELOS (C1,LT 0.00) =	0.611
VMICI (C1,LT-2.00) =	0.100	VMICI (C1,LT-0.80) =	1.556	VMICI (C1,LT 0.00) =	7.210
AINST (C0,LT 0.00) =	0.000	VINST (C0,LT 0.00) =	1.350	THETA (C0,LT 0.00) =	0.000
CHISQ (C0,LT 0.00) =	145.028				

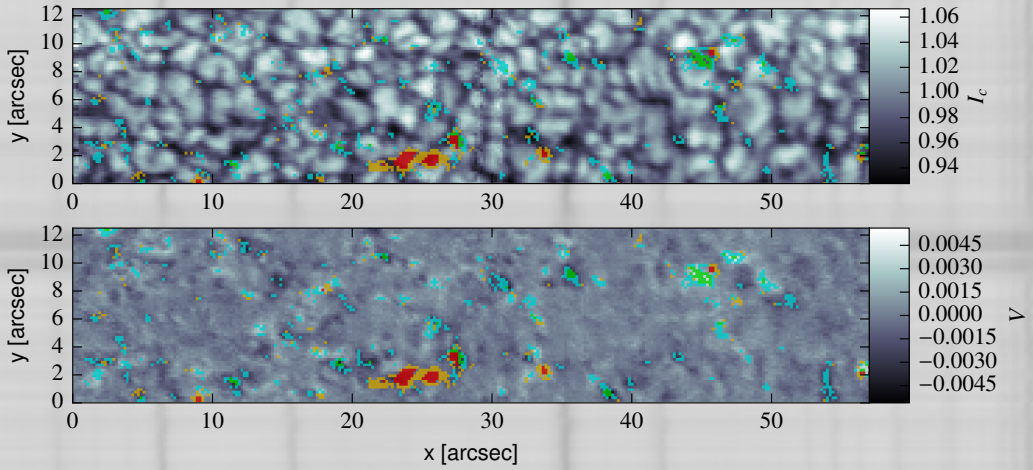
Comparison: 1-D, 2-D, MLR maps

1-D SIR



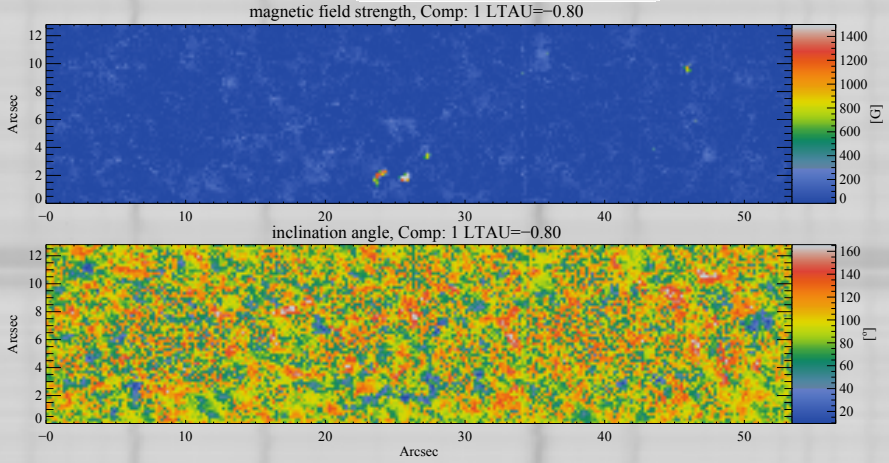
Comparison: 1-D, 2-D, MLR maps

MLR-technique



Comparison: 1-D, 2-D, MLR maps

2-D SPINOR



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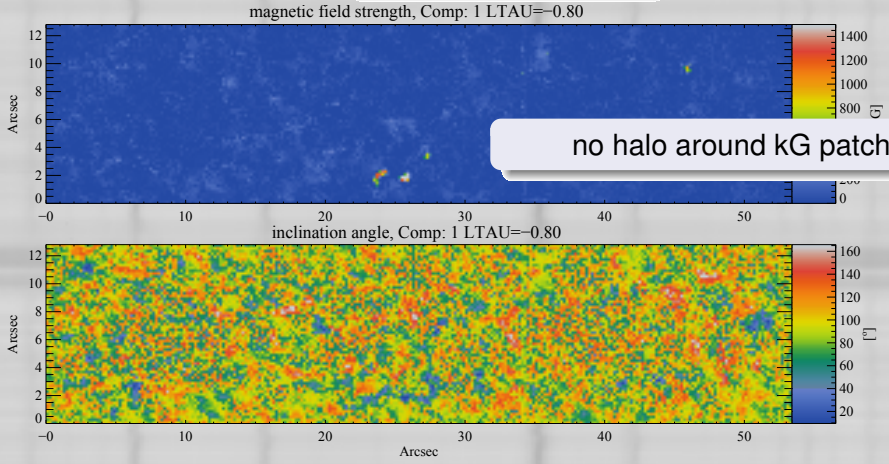
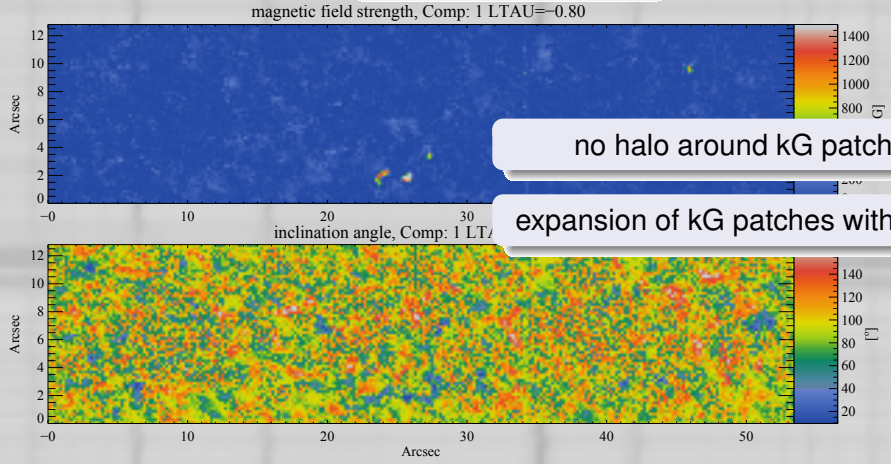
2-D SPINOR



no halo around kG patches

Comparison: 1-D, 2-D, MLR maps

2-D SPINOR

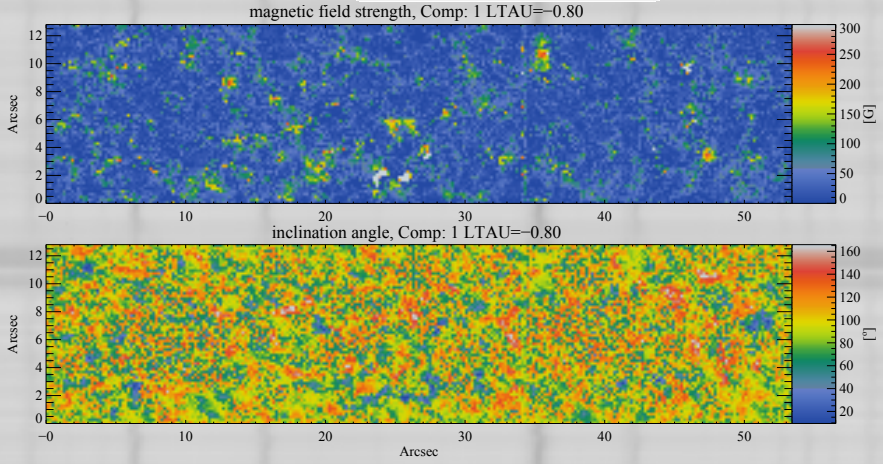


no halo around kG patches

expansion of kG patches with height

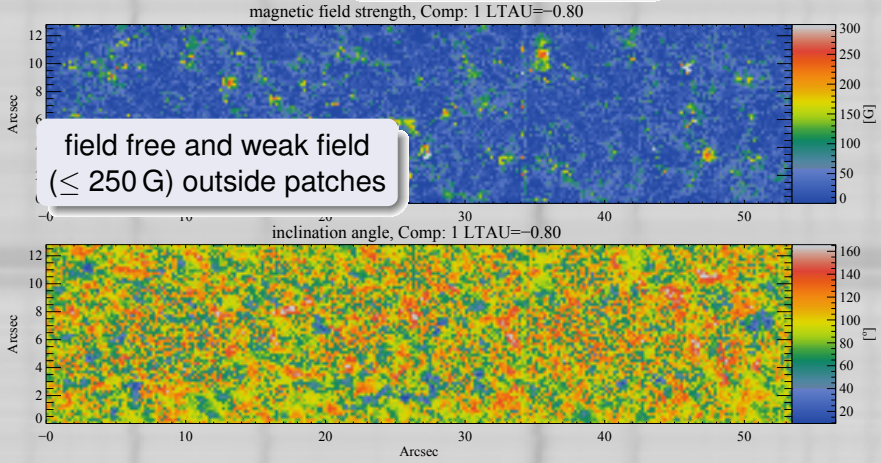
Comparison: 1-D, 2-D, MLR maps

2-D SPINOR



Comparison: 1-D, 2-D, MLR maps

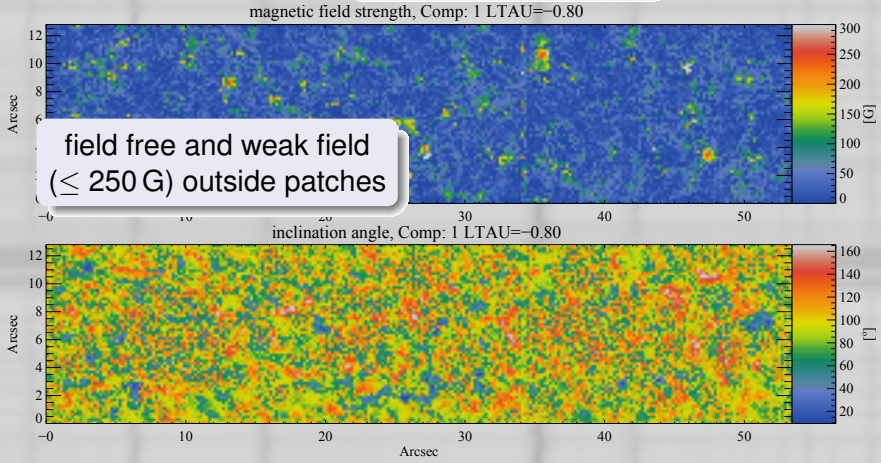
2-D SPINOR



field free and weak field (≤ 250 G) outside patches

Comparison: 1-D, 2-D, MLR maps

2-D SPINOR



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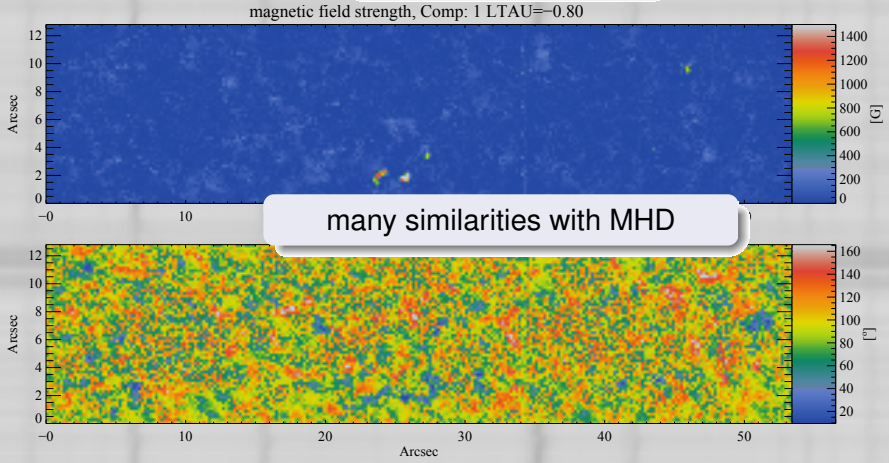
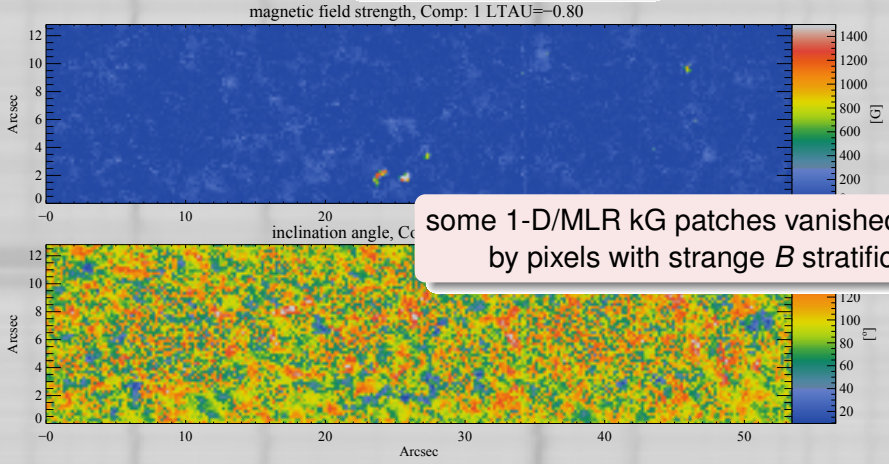


many similarities with MHD

Comparison: 1-D, 2-D, MLR maps

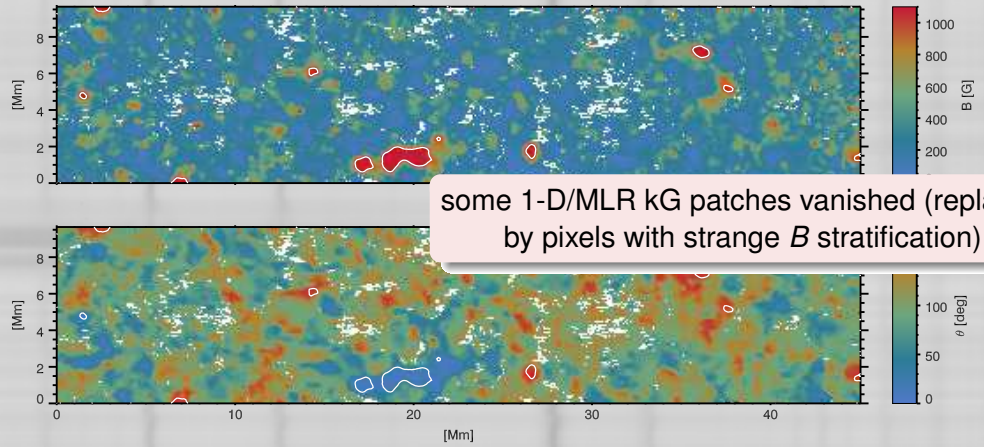
2-D SPINOR



some 1-D/MLR kG patches vanished (replaced by pixels with strange B stratification)

Comparison: 1-D, 2-D, MLR maps

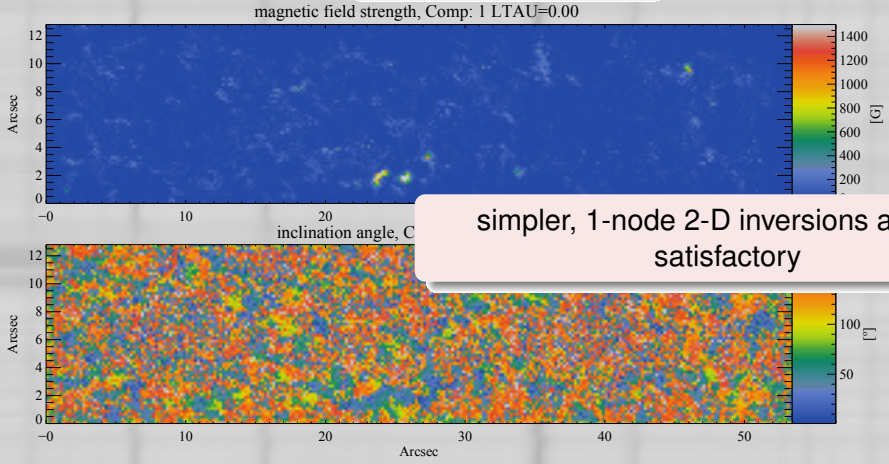
1-D SIR



some 1-D/MLR kG patches vanished (replaced by pixels with strange B stratification)

Comparison: 1-D, 2-D, MLR maps

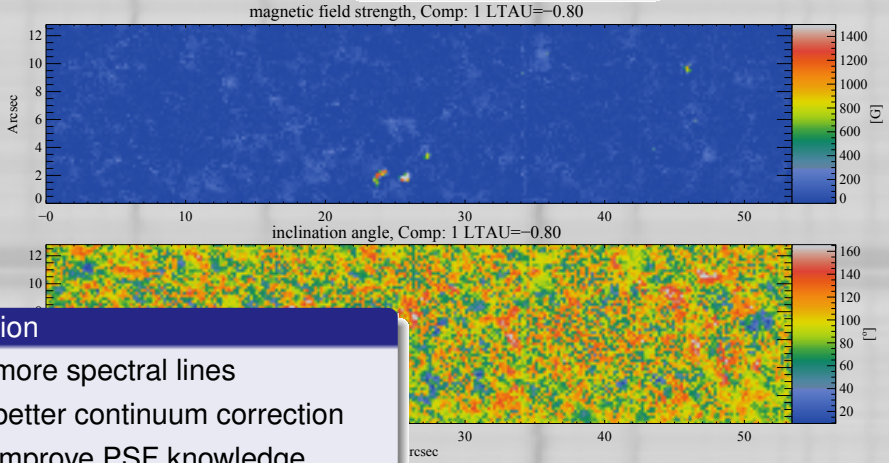
2-D SPINOR - 1 node



simpler, 1-node 2-D inversions also not satisfactory

Comparison: 1-D, 2-D, MLR maps

2-D SPINOR



Solution

- more spectral lines
- better continuum correction
- improve PSF knowledge

Summary

2-D inversions with GRIS data

- reproduces complex Stokes profiles with rather simple model atmosphere
- promising behavior on kG patches
- details of PSF matter for correct height stratification
- uncertainties in complex cases (i.e., penumbra, light bridges)

→ exact PSF knowledge is mandatory (and its spatial and temporal variation)

Bibliography

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Solanki, S. K., Rüedi, I. K., & Livingston, W. 1992, A&A, 263, 312

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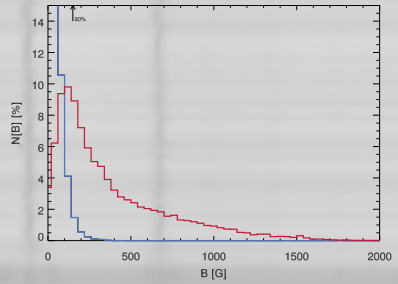
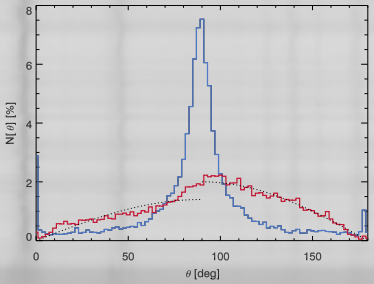
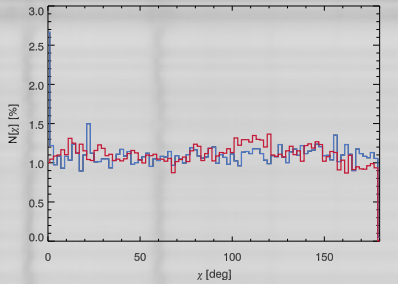
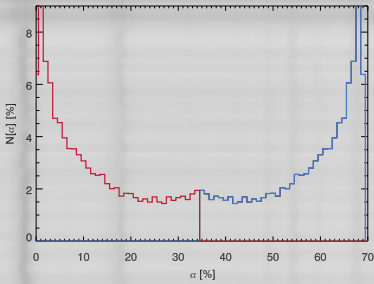
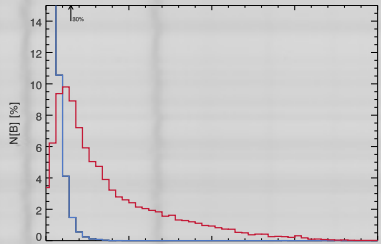
Martínez González et al. (2016) - PDFs

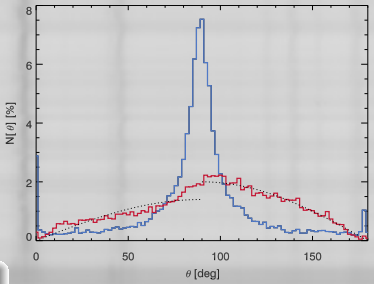












Meaning of α

- filling factor: unresolved fine structure within one pixel
- straylight contribution