Wide-Field Polarimetry: A Unique Probe of Interstellar Turbulence

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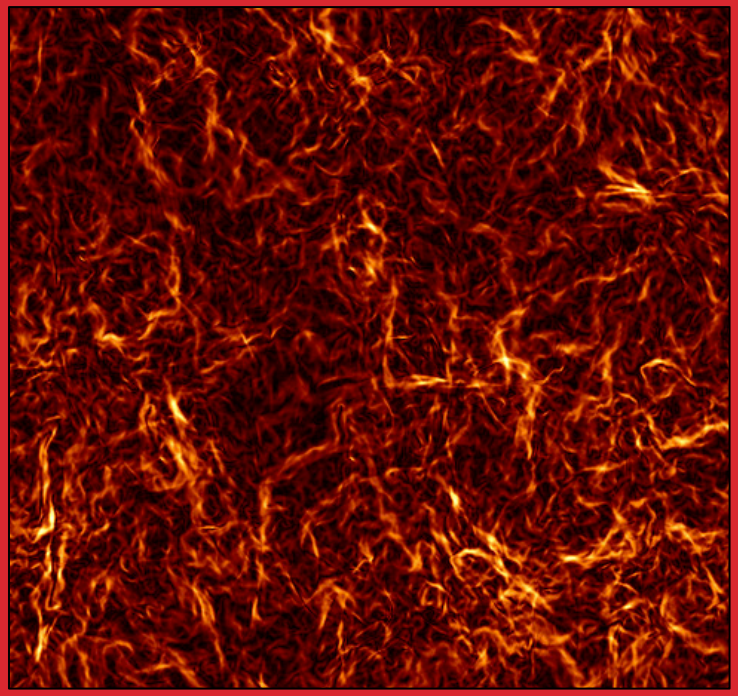
#CRISM2014



Haverkorn & Heitsch (2004)

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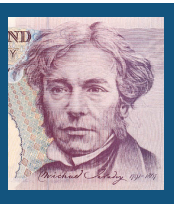
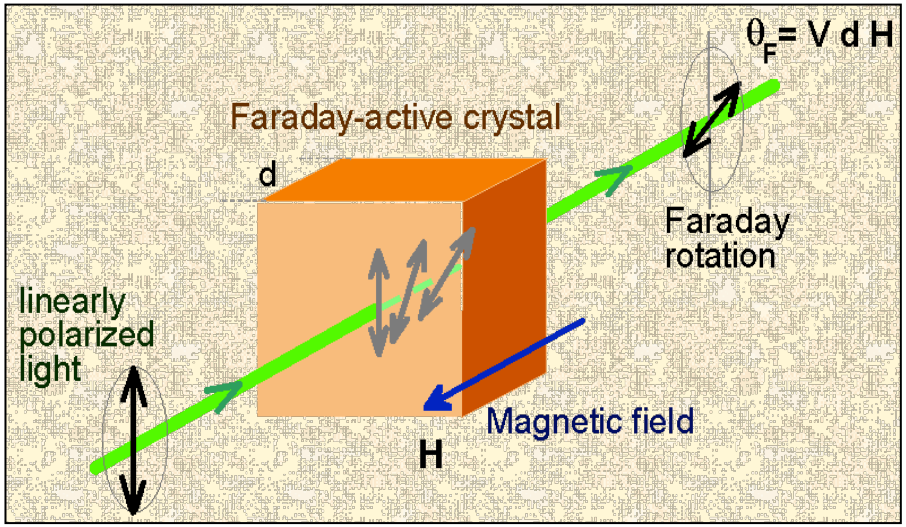
Faraday Rotation



Superconductivity Lab, Oslo University

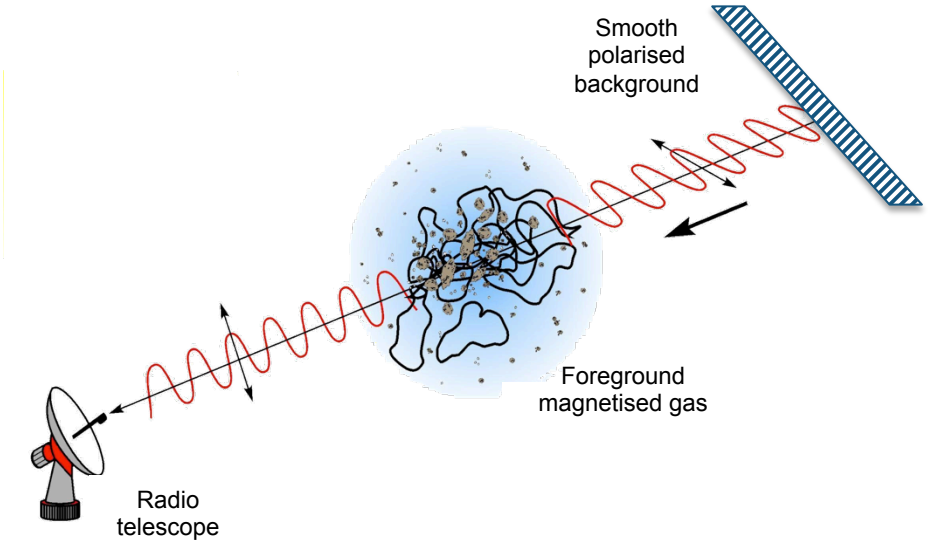


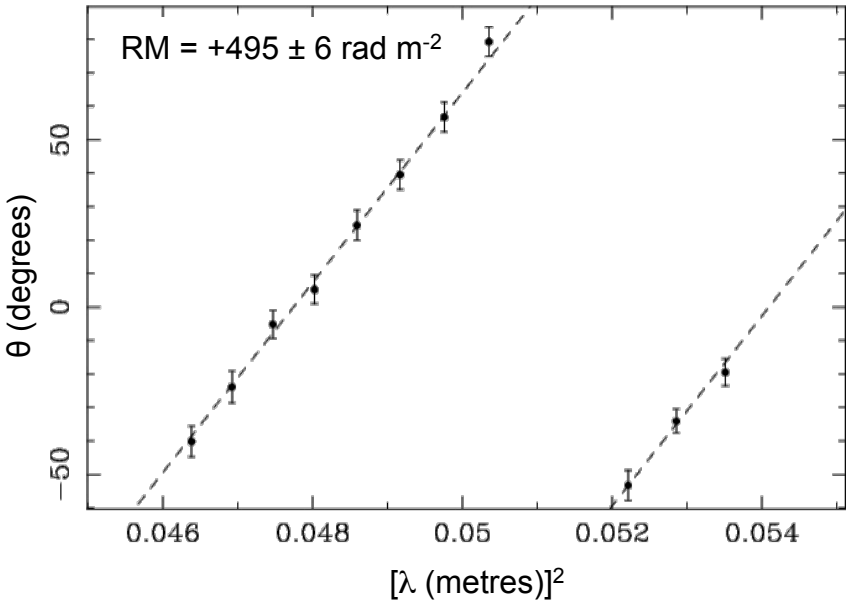
$$\theta = \theta_0 + \mathrm{RM}\,\lambda^2$$

$$\mathrm{RM} = K\int_L^0 n_e \vec{B}\cdot d\vec{l}$$

(RM = rotation measure)

Philipp Kronberg / Physics Today





Pulsar B1154-62 (Gaensler et al. 1998)

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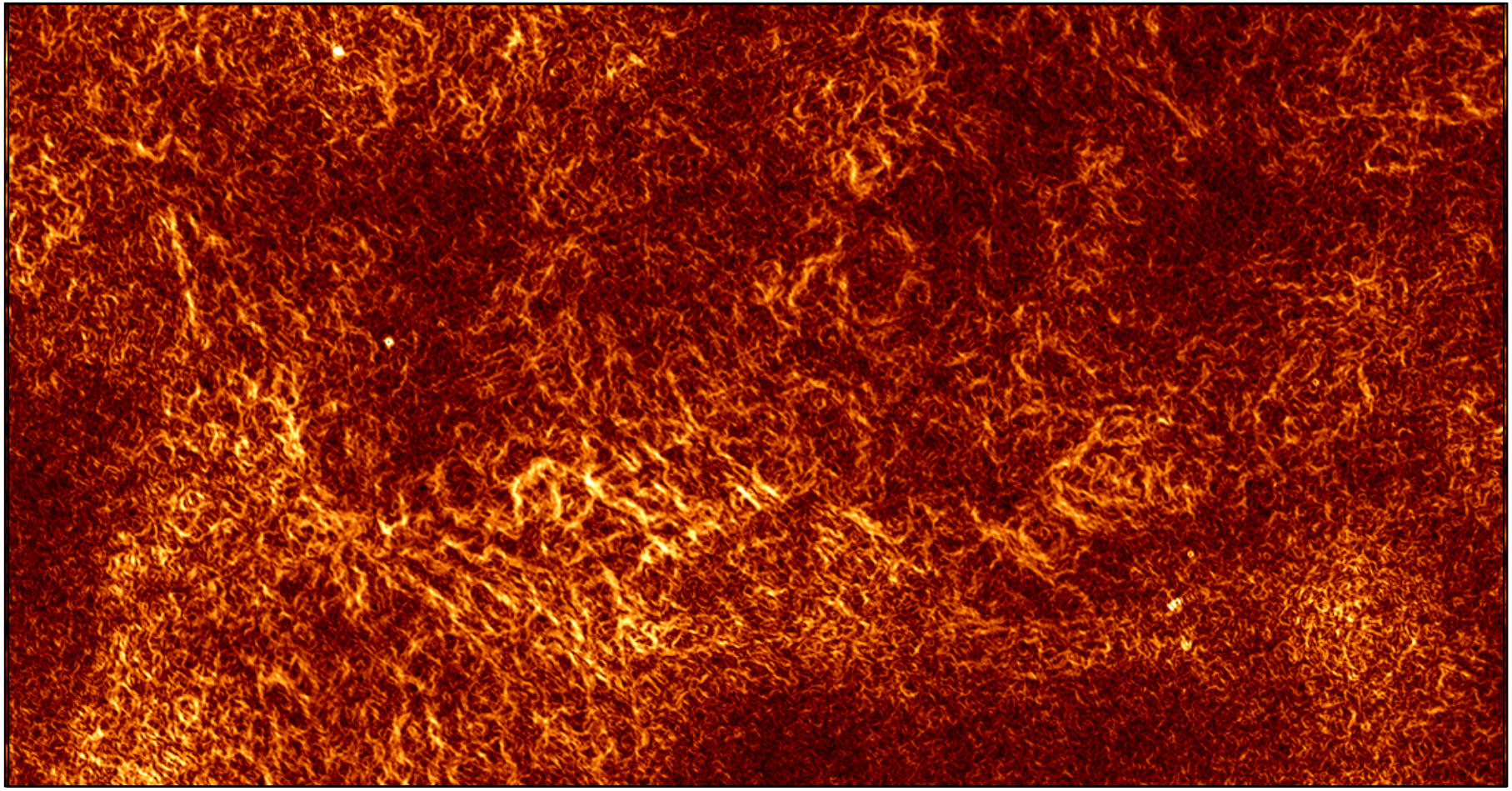
Faraday Rotation

The Polarisation Gradient

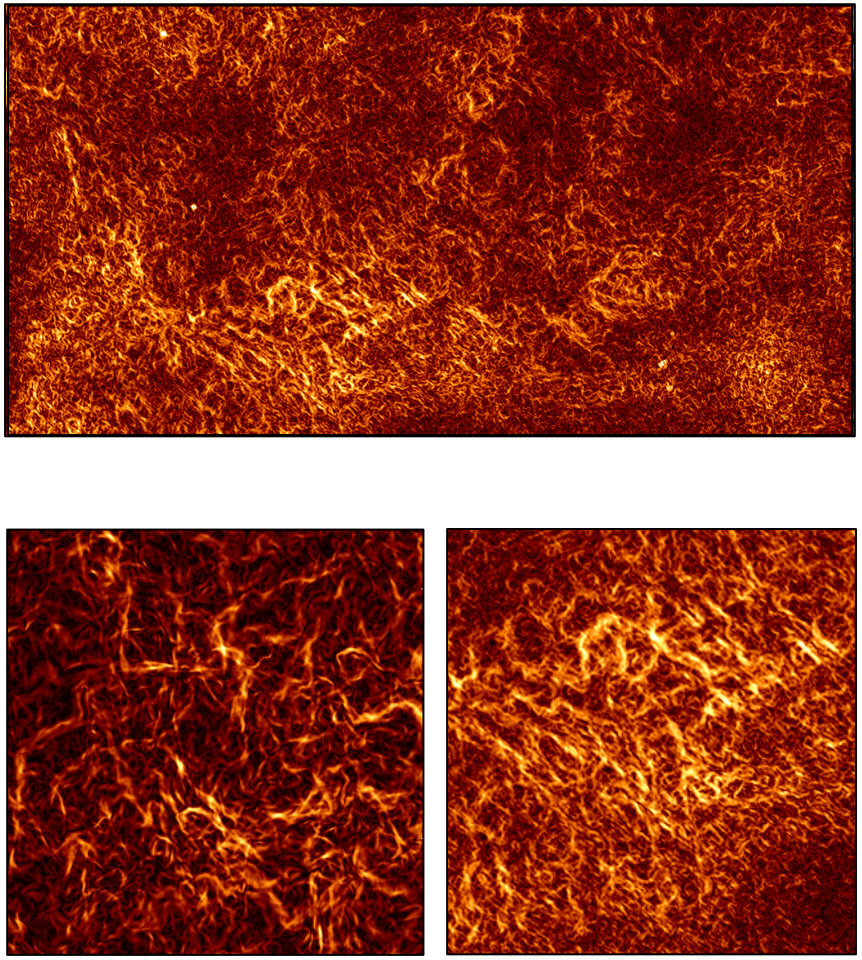


Snakes in the Plane

- Mottled morphology of $\boldsymbol{P} \equiv Q + iU$ due to fluctuations in foreground RM as function of sky position
- Structures that induce these fluctuations can be revealed through *gradient* of linear polarisation:

$$|\nabla P| = \sqrt{\left(\frac{\partial Q}{\partial x}\right)^2 + \left(\frac{\partial Q}{\partial y}\right)^2 + \left(\frac{\partial U}{\partial x}\right)^2 + \left(\frac{\partial U}{\partial y}\right)^2}$$

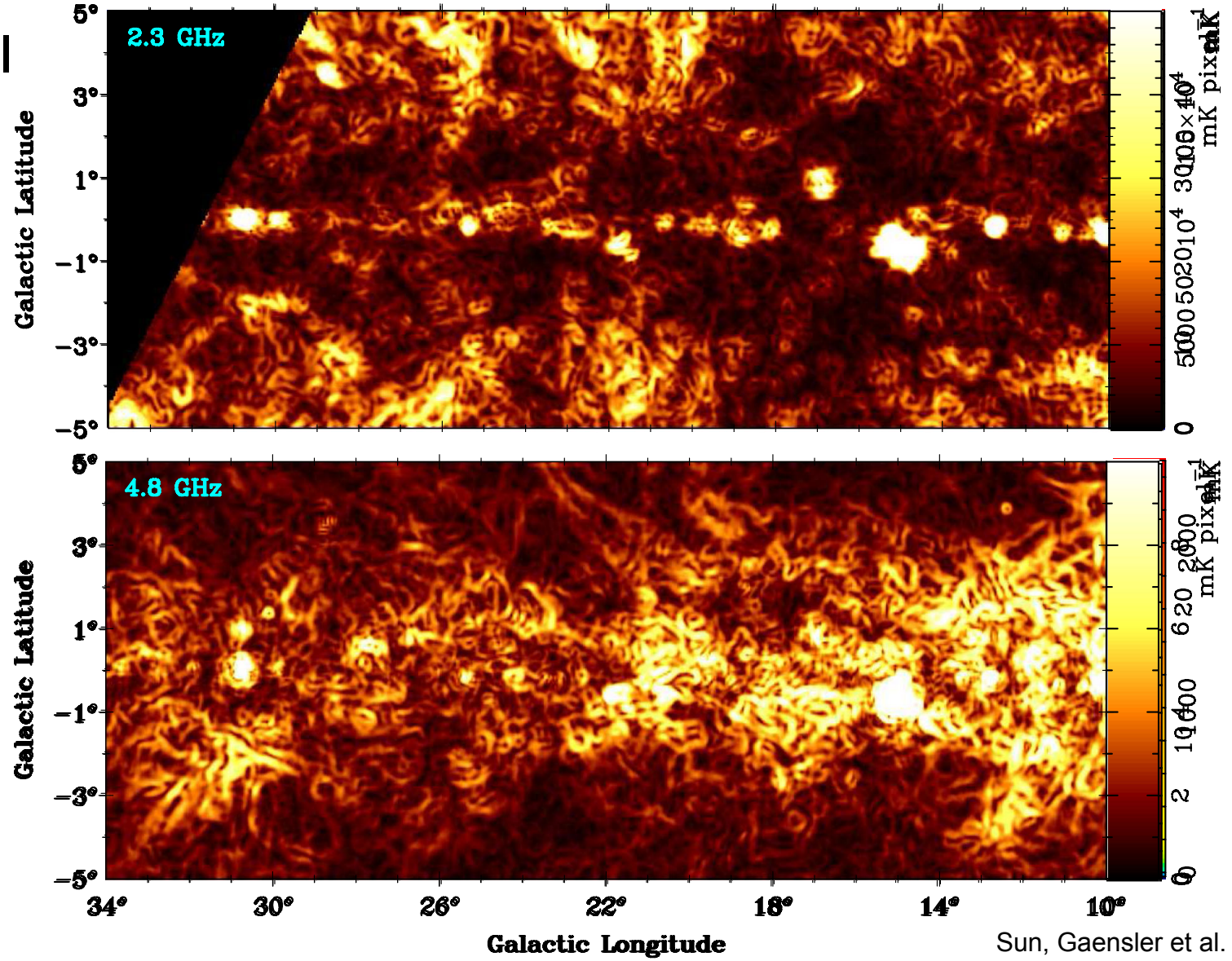
  - cusps/jumps in foreground electron density or magnetic field
- Similar structures seen in simulations; produced by shocks, vortices, shear (Burkhart, Lazarian & Gaensler 2012; Iacobelli, Gaensler et al. 2014)
  - *direct visualisation of interstellar turbulence*



Gaensler et al. (2001, 2011)

|∇P| for MHD simulations and observations (Haverkorn & Heitsch 2004; Gaensler et al. 2011)

Are We Sure It's Turbulence?



Sun, Gaensler et al. (2014)

Are We Sure It's Turbulence?

› For $\boldsymbol{P}$ = Q + iU and $\mathcal{p}$ = $|\boldsymbol{P}|$, compute structure functions:

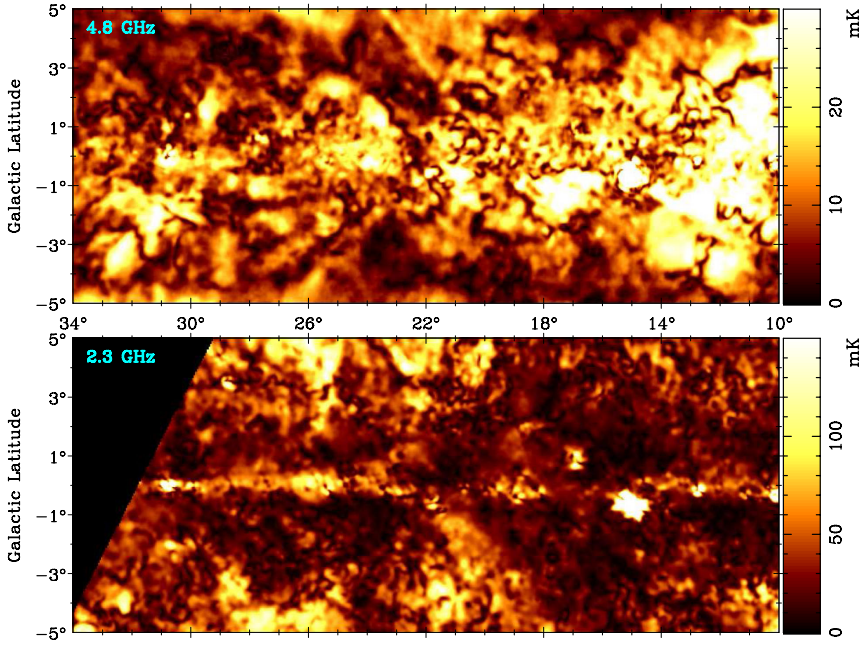
$$SF_{\boldsymbol{P}}(dx) \equiv \langle |\boldsymbol{P}(x) - \boldsymbol{P}(x + dx)|^2 \rangle \qquad SF_{\mathcal{p}}(dx) \equiv \langle |\mathcal{p}(x) - \mathcal{p}(x + dx)|^2 \rangle$$

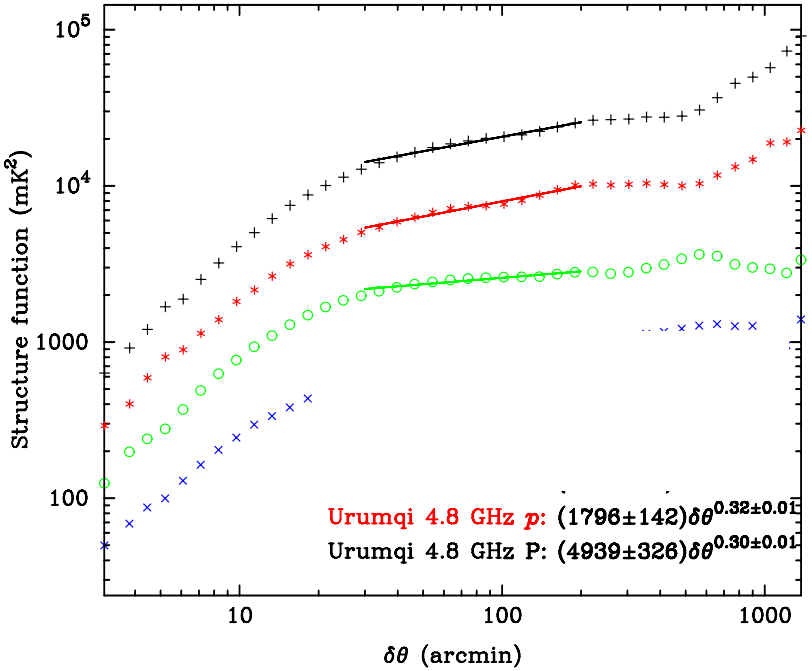
- for intrinsic polarisation, no correlation between intensity and angle

  → $SF_{\boldsymbol{P}}(dx)$ and $SF_{\mathcal{p}}(dx)$ should be power laws with same slopes

- for Faraday rotation, anti-correlation between angle fluctuations and intensity

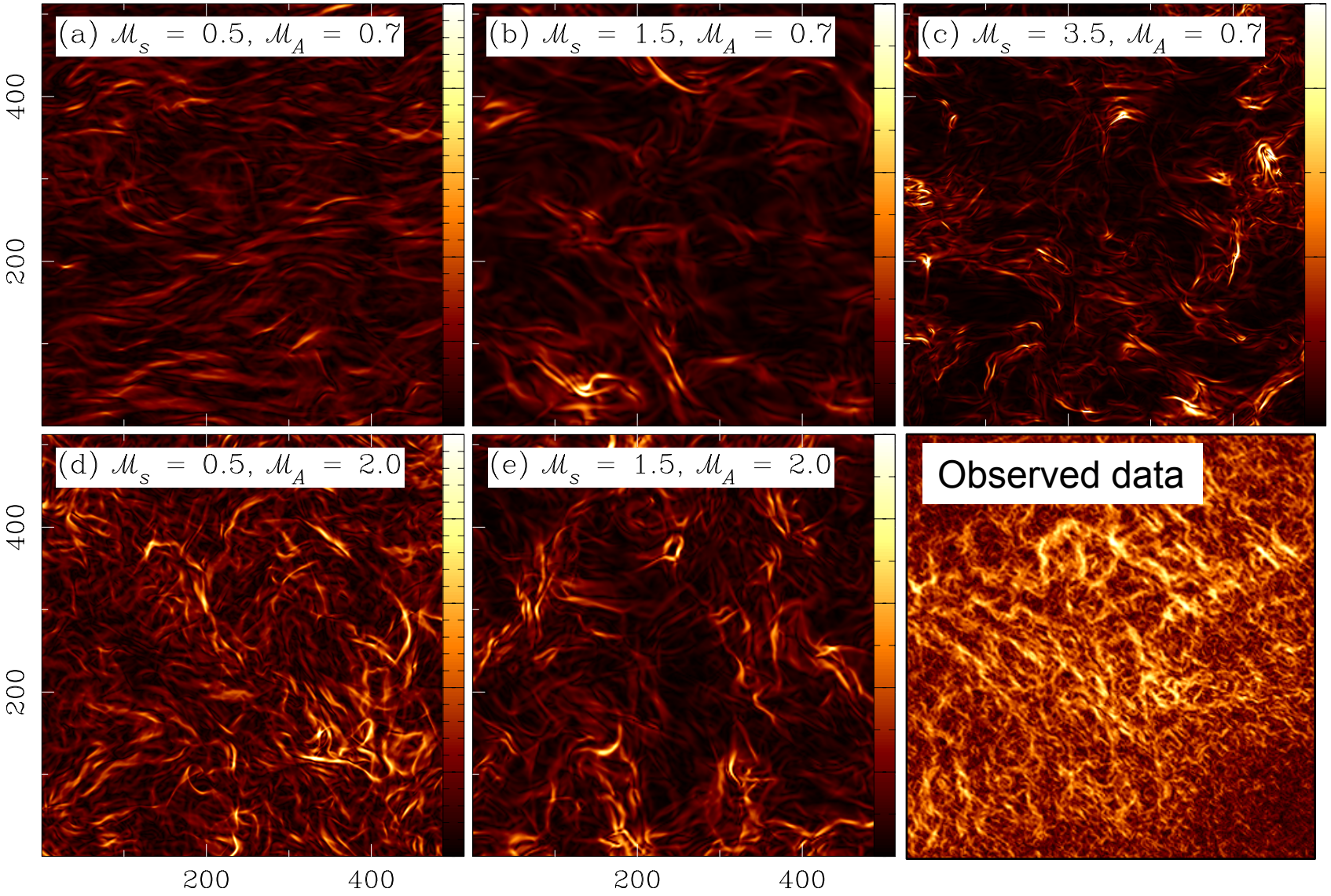
  → $SF_{\boldsymbol{P}}(dx)$ and $SF_{\mathcal{p}}(dx)$ should be power laws with different slopes





Sun, Gaensler et al. (2014)

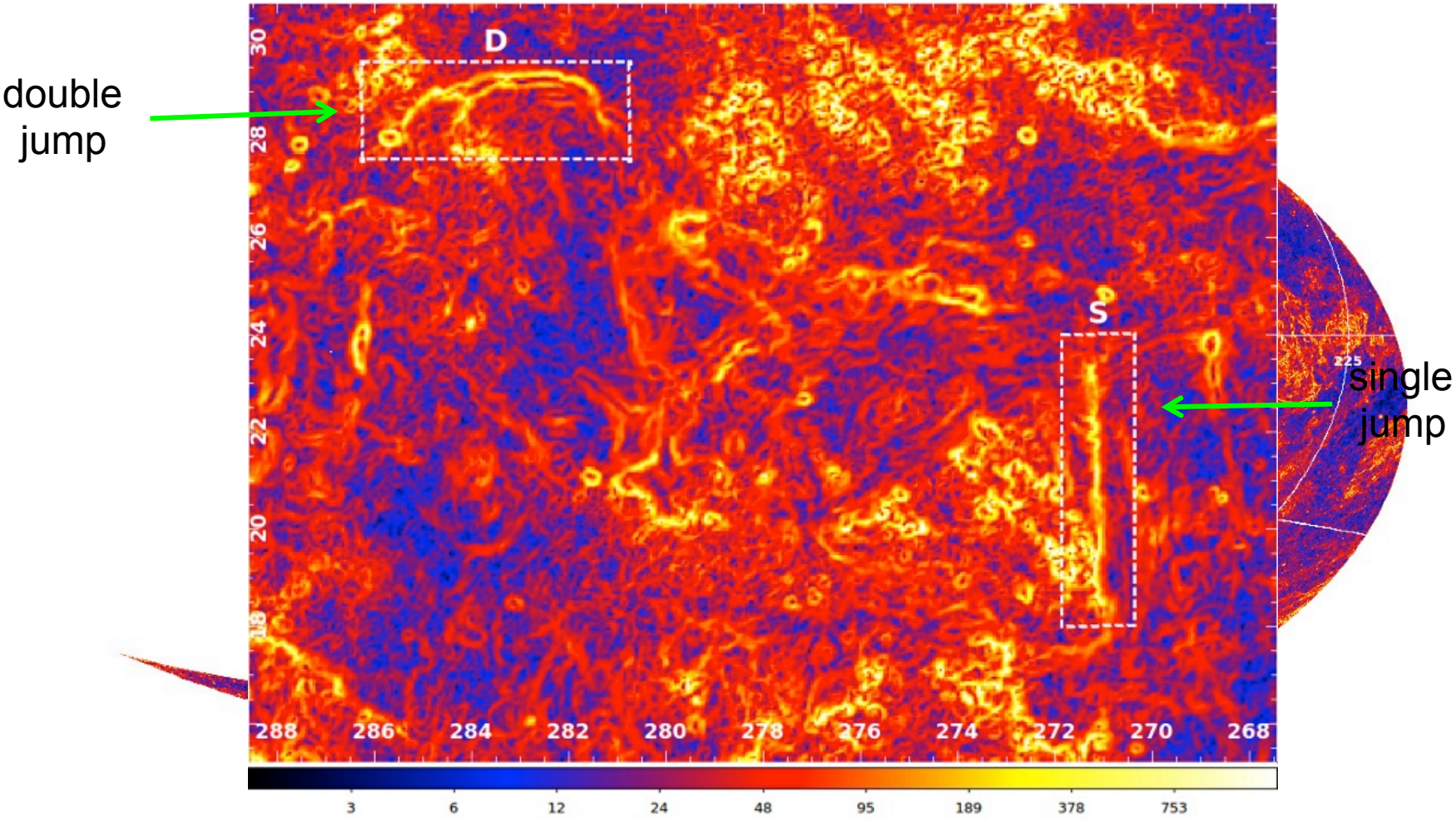
Quantitative Investigations



Gaensler et al. (2011)

Wide-Field Polarimetry

2.4 GHz all-sky polarisation gradient (Iacobelli, Gaensler et al. 2014)



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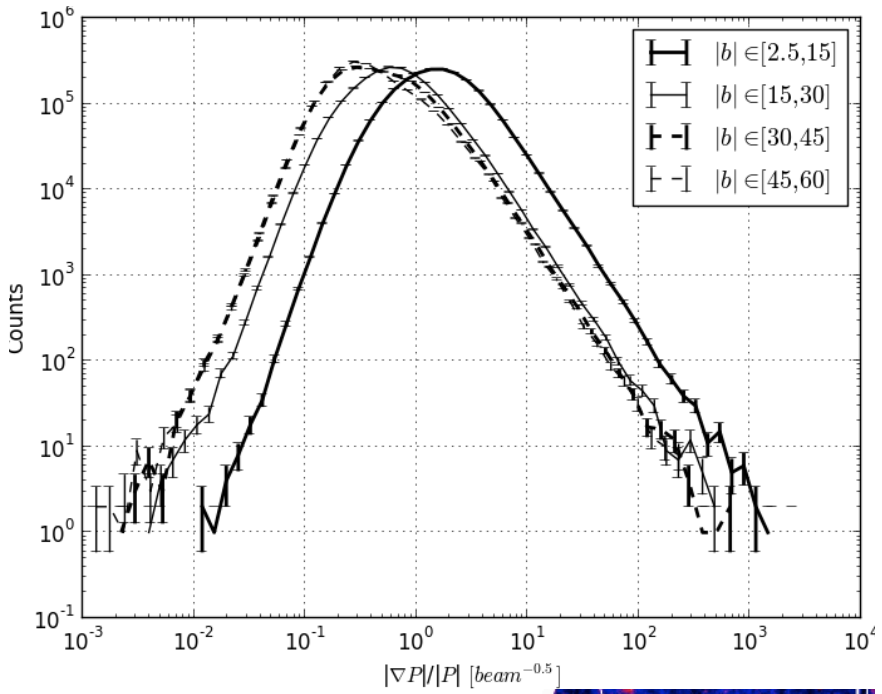

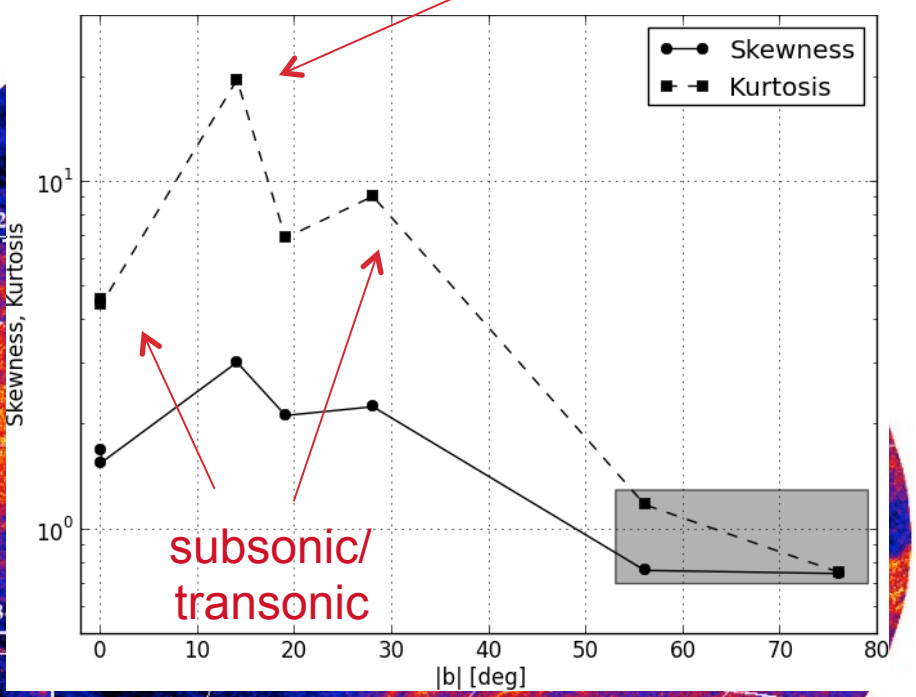

Conclusions

- Galaxy is suffused with $\nabla \boldsymbol{P}$ filaments
  - loci of cusps & edges in foreground n_e or B
  - stochastic network of turbulence & shocks
  - morphology & moments → sonic Mach number

- Work in progress:
  - frequency-dependence of $\nabla \boldsymbol{P}$ (Purcell +2014)
  - comparison of $\nabla \boldsymbol{P}$ & ∇RM (Geisbuesch+ 2014)
  - additional geometric diagnostics (Herron+ 2014)
  - low frequencies → local structure (Lenc+ 2014)

- Gradient of polarisation can:
  - directly visualise turbulence in diffuse gas
  - give quantitative info on turbulent parameters