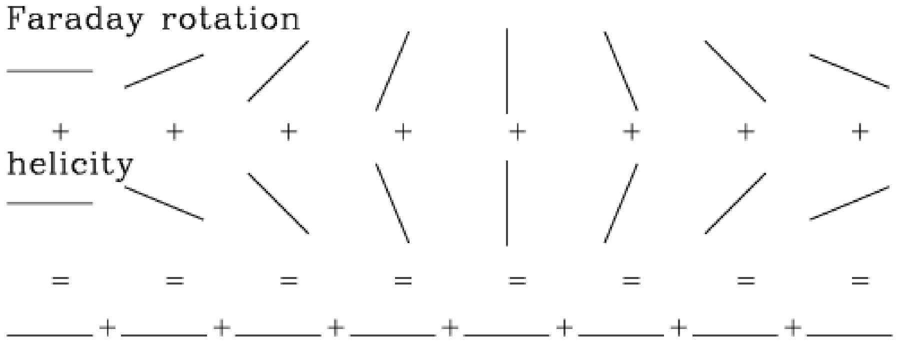
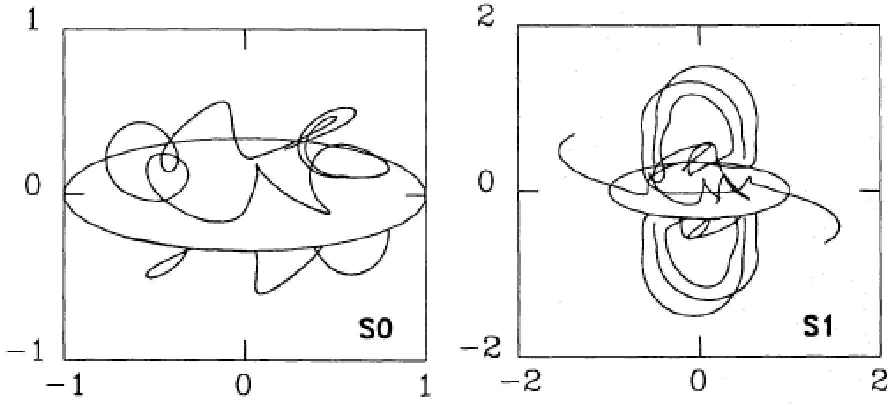
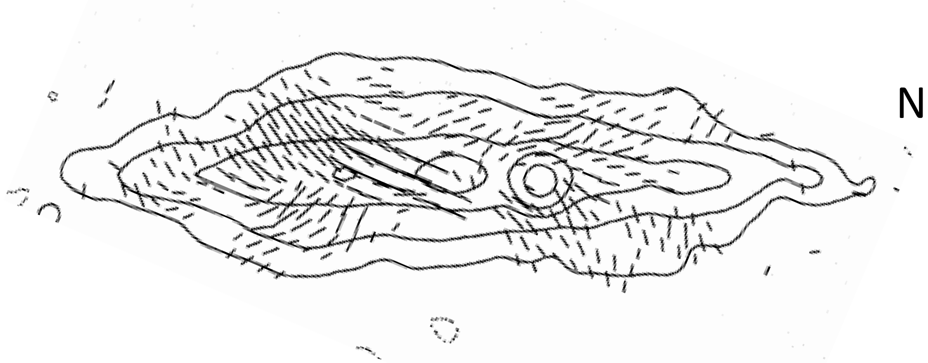
Polarized intensity oddities in edge-on galaxies

Axel Brandenburg (Nordita)

- Faraday rotation: rotates ***B*** field
- → Faraday depolarization
- Helicity also rotates the field
    - o Can either compensate → cancels depolarization → enhanced polarized intensity
    - o Or enhance depolarization
- Happens in 2 opposing quadrants







NGC 891

Brandenburg & Stepanov (2014)
Horellou & Fletcher (2014)

Singly helical field

Stokes Q and U parameters $P = Q + iU$

$$Q = p_0 \int_{-\infty}^{\infty} \varepsilon \cos 2\left(\psi + \phi\lambda^2\right) dz$$

$$U = p_0 \int_{-\infty}^{\infty} \varepsilon \sin 2\left(\psi + \phi\lambda^2\right) dz$$

Intrinsic polarized emission from B

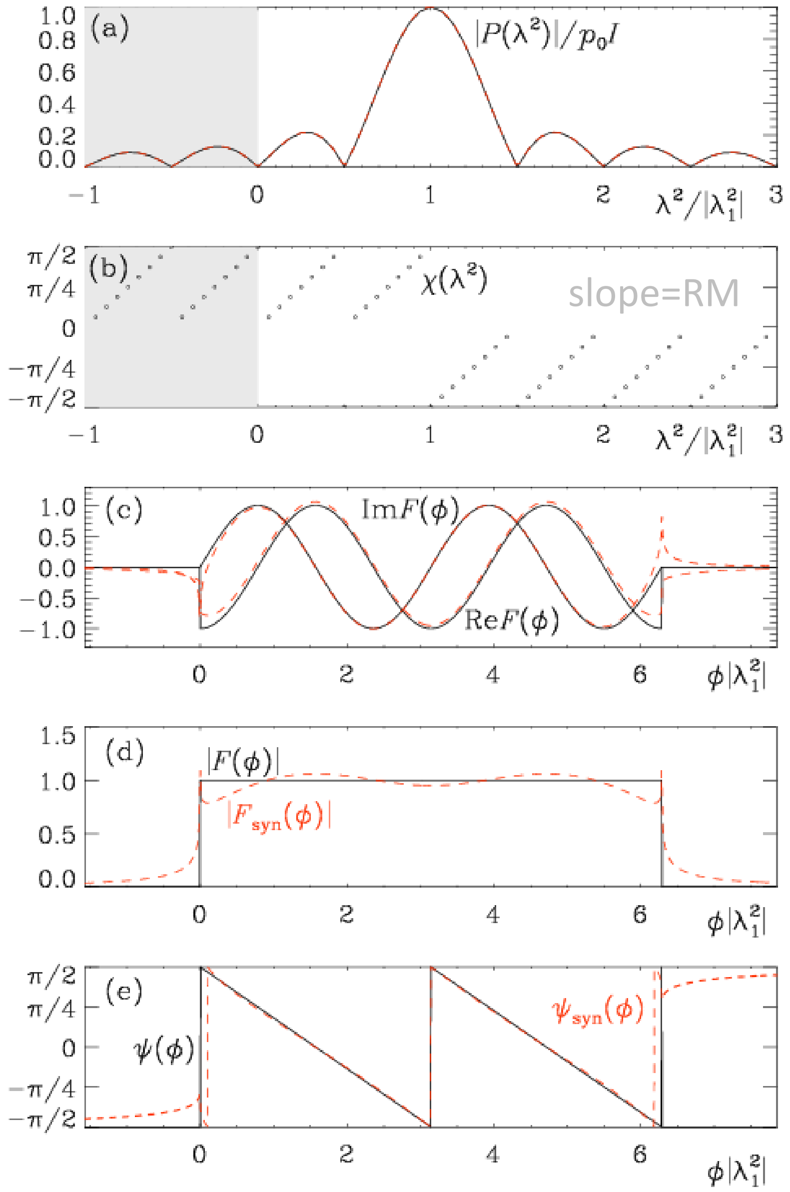
$$B_\perp = \left|B_\perp\right| e^{i\psi_B}, \quad \psi = \psi_B + \tfrac{1}{2}\pi$$

Cancellation condition

$$\psi = -kz, \quad \phi = -K n_{\rm th} B_0 z$$

Helical field w/ positive helicity

$$\mathbf{B} = \begin{pmatrix} B_1 \cos kz \\ -B_1 \sin kz \\ B_0 \end{pmatrix}$$



Only works if RM > 0 and k > 0

Peak determined by single parameter

$$\lambda_1^2 = -k / K n_{th} B_0 \propto k / \mathrm{RM}$$

But difficult/impossible to recover F(ϕ)

(Burn 1966)

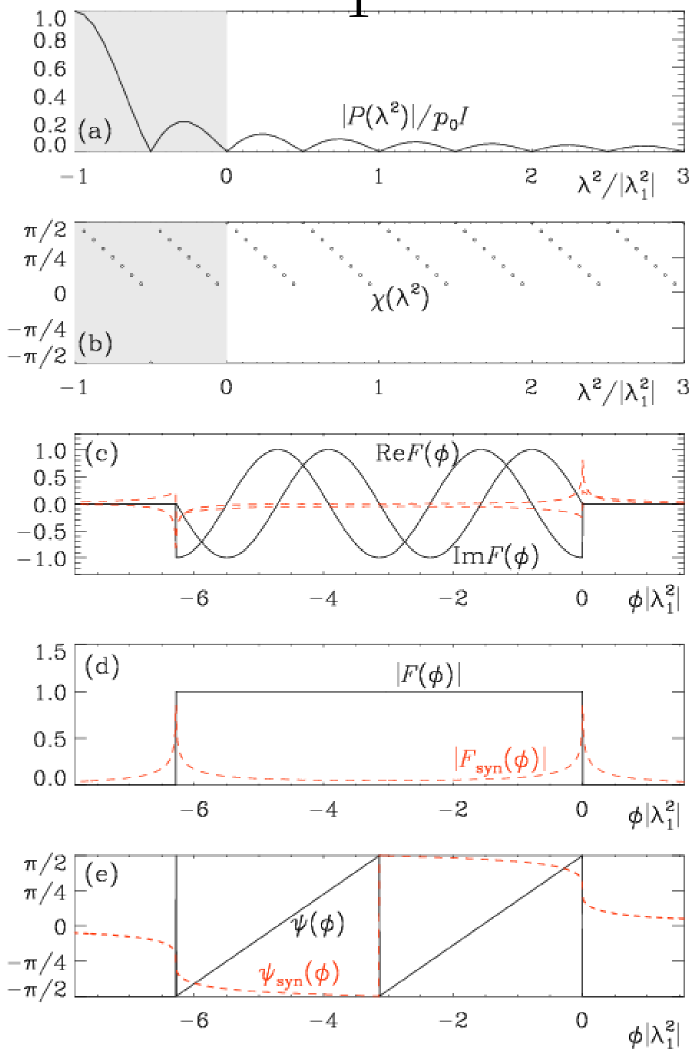
$$P(\lambda^2) = \int_{-\infty}^{\infty} F(\phi) e^{2i\phi\lambda^2} \, d\phi$$

$$F(\phi) = \frac{1}{2\pi} \int_{-\infty}^{\infty} P(\lambda^2) e^{-2i\phi\lambda^2} \, d(2\lambda^2)$$

Positivity:

$$F_{syn}(\phi) = \frac{1}{2\pi} \int_{0}^{\infty} P(\lambda^2) e^{-2i\phi\lambda^2} \, d(2\lambda^2)$$

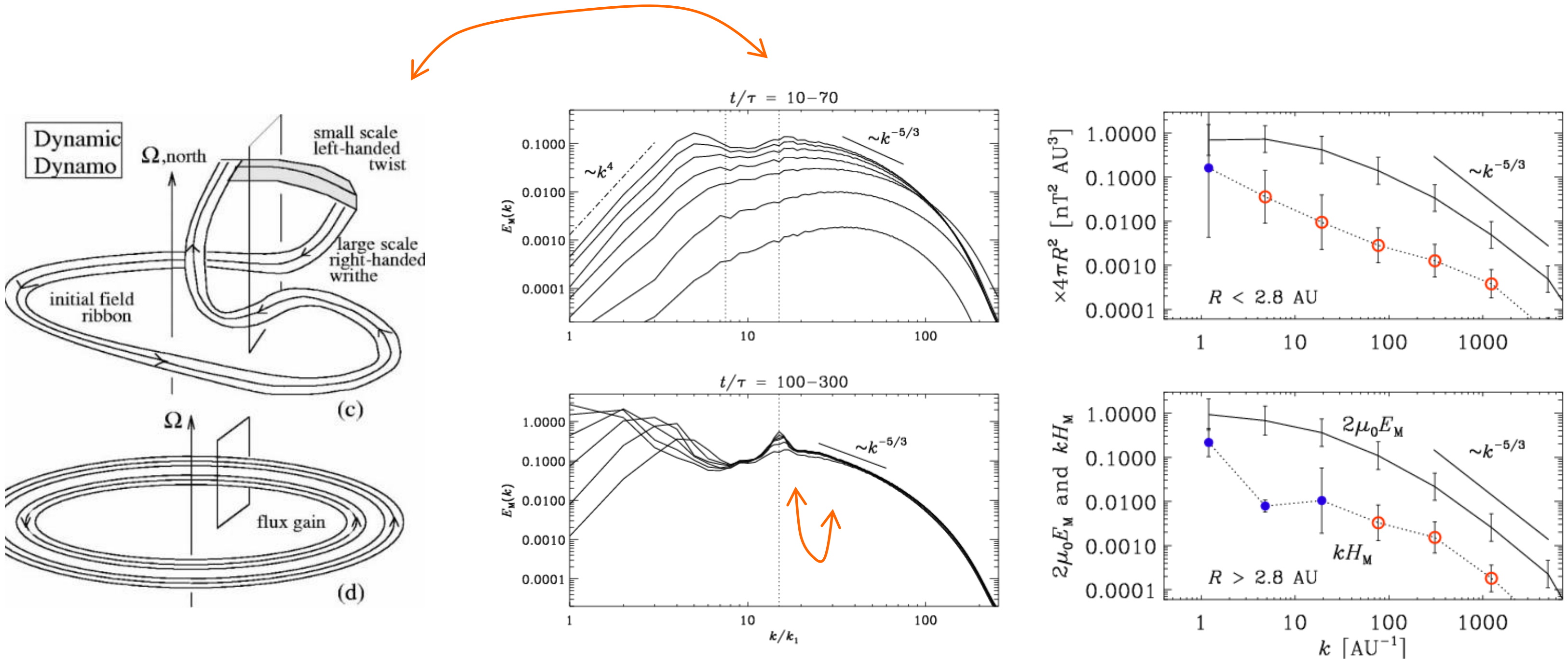
$$\lambda_1^2 < 0$$



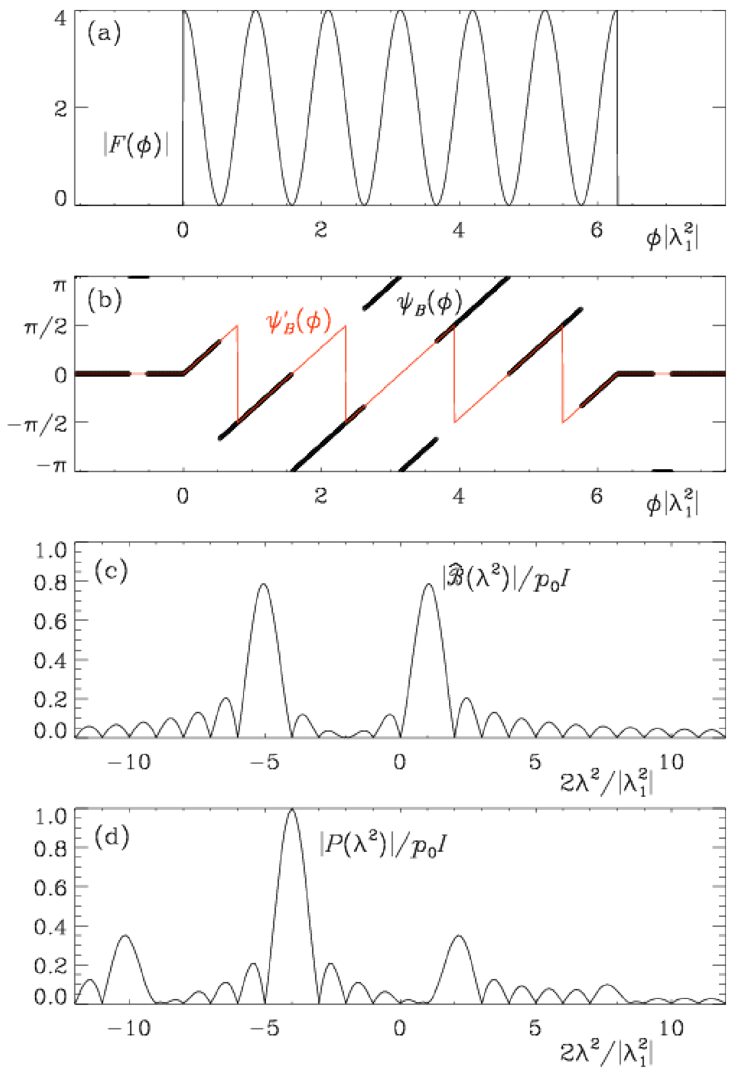
Expect bi-helical fields

- Magnetic helicity conserved
- Inverse cascade produces small-scale waste!
- Opposite sign of helicity (or k)

Blackman & Brandenburg (2003)



π ambiguity lead to "line splitting"



Peaks at k_1=1 and k_2=-5

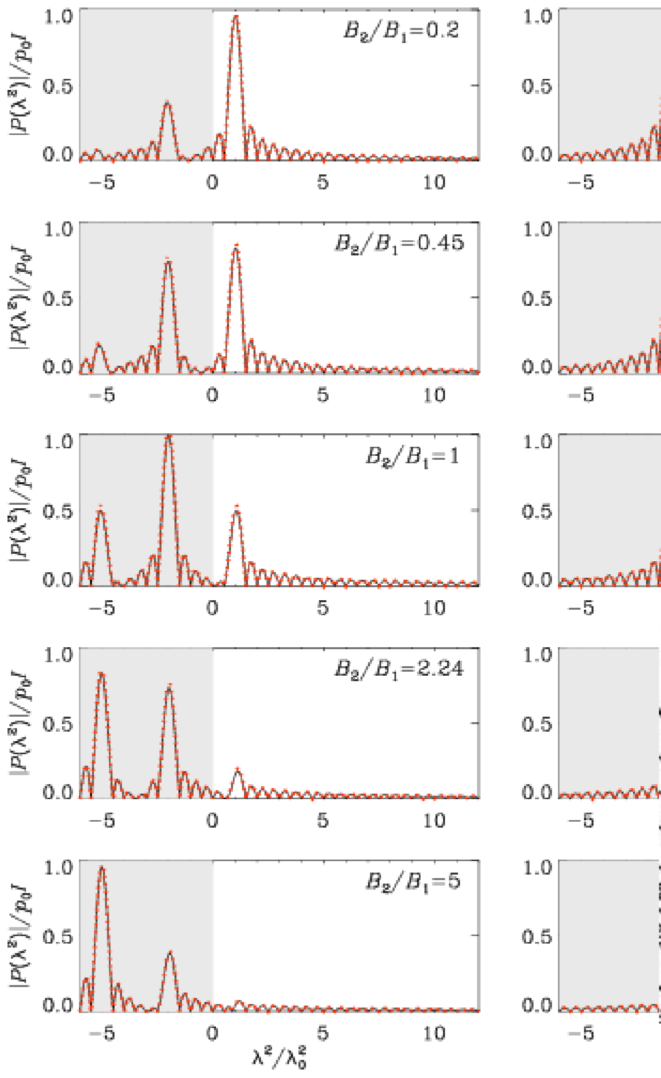
translate to k_1+k_2 = -4
and to k_1-k_2 = 6

(i) peak in P at -4
peak separation 6

(ii) in Faraday dispersion:
frequency 6
-2x phase gradient -4

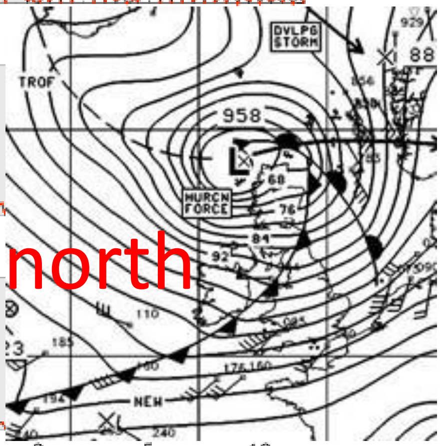
For RM>0, only +ve helicity obs

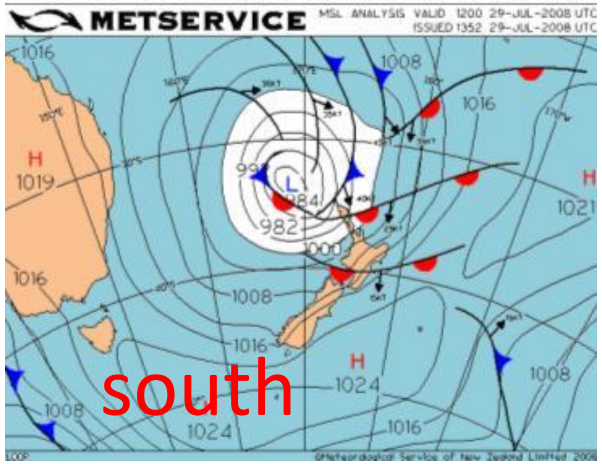
RM > 0 RM < 0



For RM > 0,
Left: north
Right: south

For RM < 0,
Left: south
Right: north





Scales and applications

$$z \leftrightarrow \phi$$

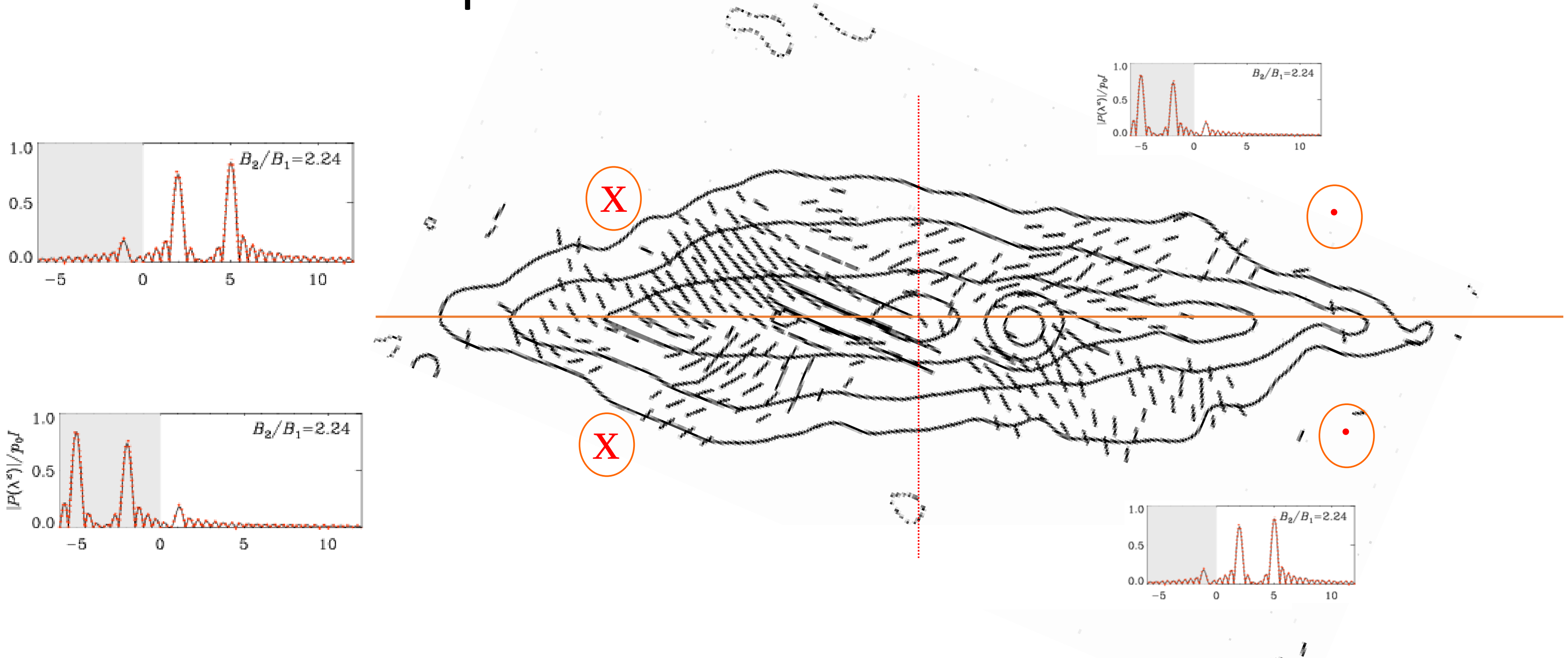
$$k \leftrightarrow \lambda^2$$

- L = 1 kpc → k = 6 kpc^{-1} → l=30 cm
- L<0.1 kpc → k > 60 kpc^{-1} → l=1 m
- Assuming B = 3 μG, n_e=0.03 cm^{-3}

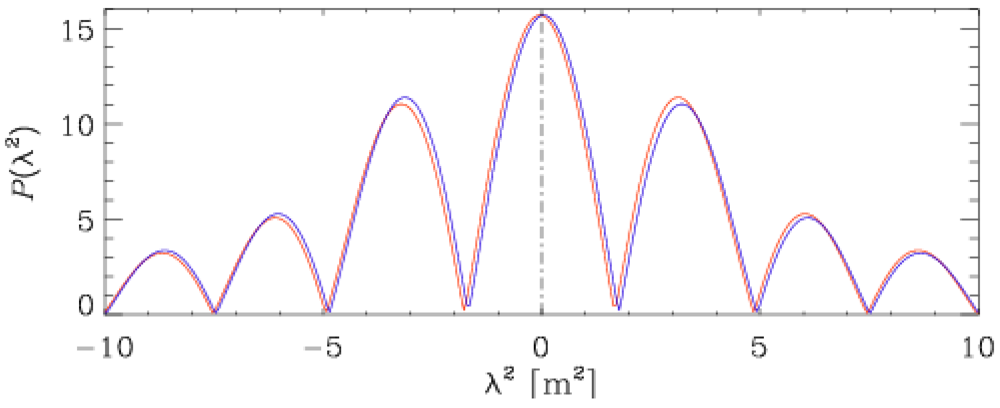
λ coverage only possible with SKA: 2 cm – 6m

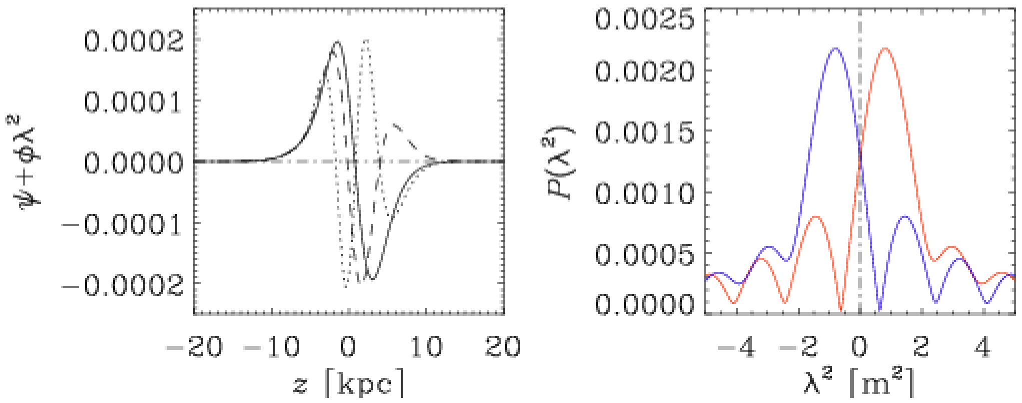
Edge-on galaxies (expectation)

- RM synthesis: measure magnetic helicity
- Need line of sight component: edge-on galaxy
- Expect polarized intensity only in 2 quadrants
- 2 characteristic peaks



Mean-field simulations: compare north – south





- Not much asymmetry:
- Galactic fields perhaps not very helical
  - Most amplification from shear
- Comparison with dynamo without shear

Conclusions

- Cancellation of depolarization by helicity works in principle
  - Expect strongest effect in range $0.3\text{m} < \lambda < 1\text{m}$
- Application to edge-on galaxies more pessimistic
  - But maybe effect of shear less strong?