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RESPICE PROSPICE

CRC

Center for Radio Cosmology

# Polarized synchrotron for EoR experiments

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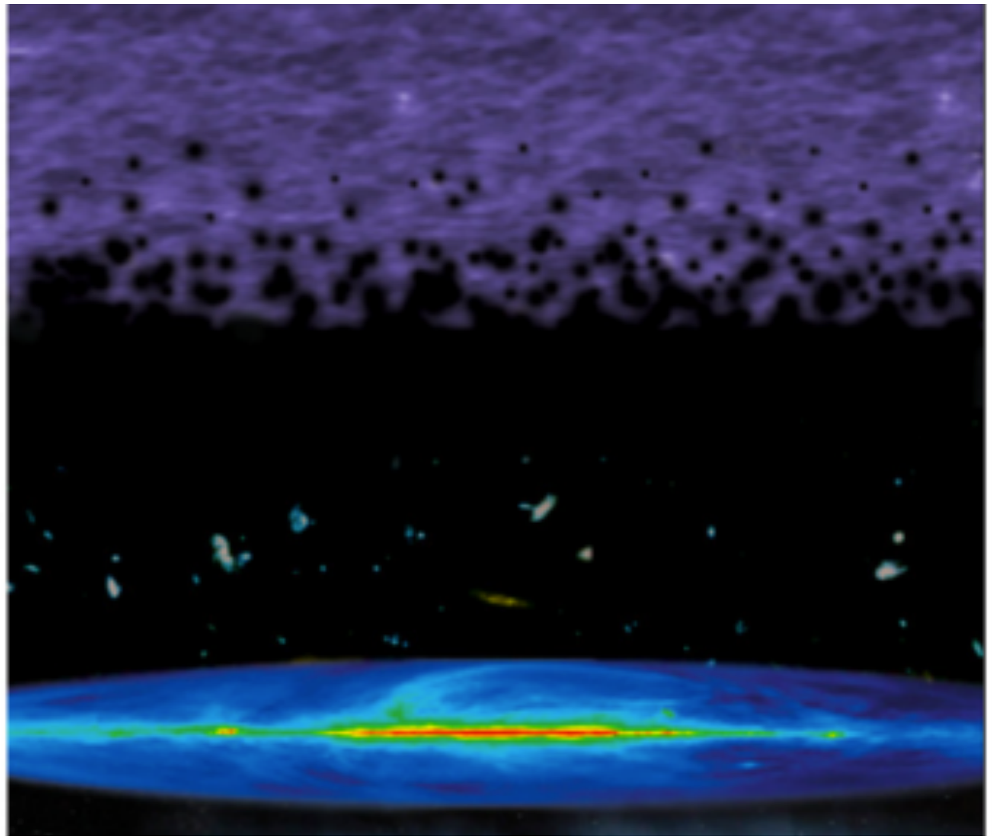
# Foregrounds for EoR

e.g. Santos et al 2005, Alonso et al 2014

foregrounds several orders of magnitude above the 21 cm signal

- Extragalactic Point Sources (PS)
  radio galaxies, AGNs, …

- Galactic and Extragalactic free-free
  low frequency radio background produced by bremsstrahlung radiation from electron-ion collisions



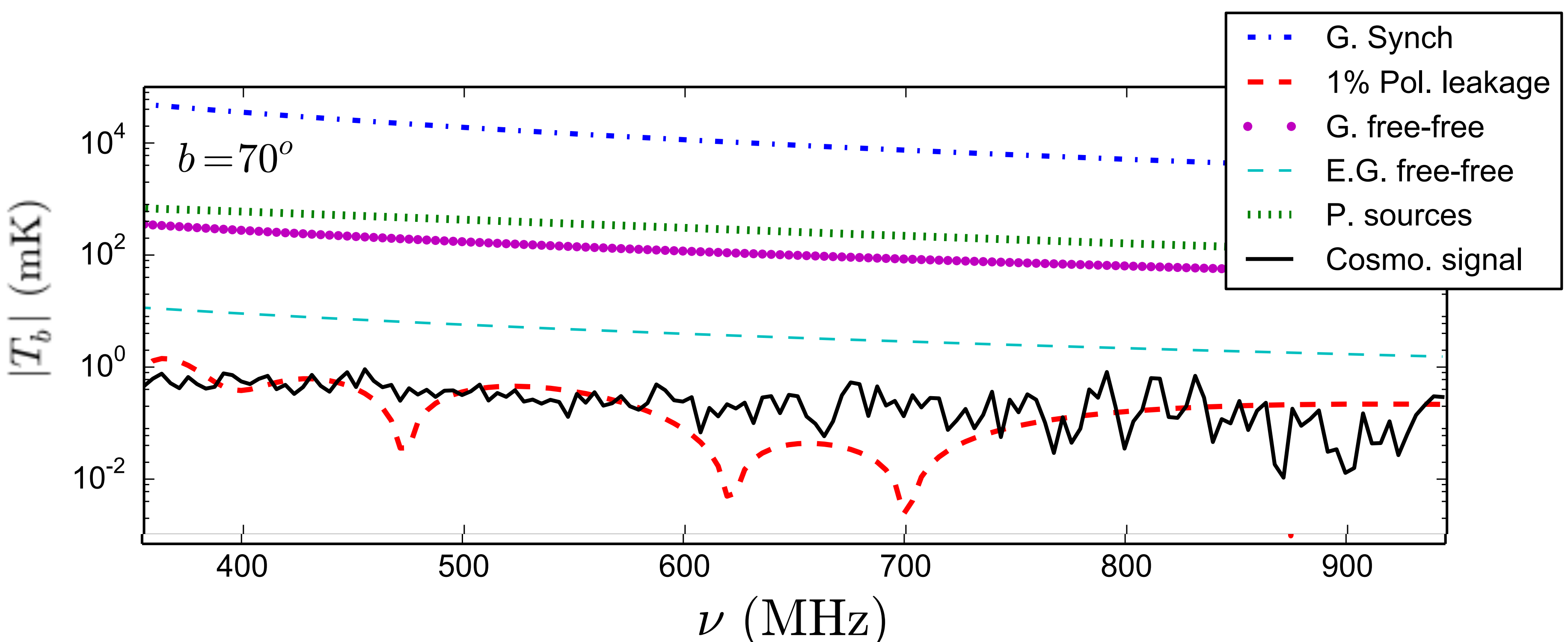

credit: LOFAR

- Galactic synchrotron (dominant foreground)
  cosmic ray electrons interacting with the galactic magnetic field

# *Polarized* Synchrotron

## Why it is important?

- spectral smoothness is the key of proper foreground subtraction
- polarized synchrotron has non trivial frequency structure
- can leak in the unpolarised part due to instrumental and calibration issues




Alonso et al 2014

# Synchrotron generalities

e.g Burn (1966)

- Depends on B _|_ to the LOS modulated by the density of *cosmic electron*
- CR power law energy density: n(E) ~ E^-p

- Diffuse polarised emission:

$$P = \Pi_0 I e^{2i\phi}$$

$$\phi = \phi_0 + \psi(s, \hat{\mathbf{n}})\lambda^2$$

faraday rotation given by B// and the presence of *thermal electrons*

$$\psi = \frac{e^3}{2\pi(m_e c^2)^2} \int_{LOS} n_e B_{||} dr$$

faraday depth or ~RM

# Rotation Measure (RM) synthesis

e.g Burn (1966), Bretjens&Bruyn (2005)

use Fourier relation between polarised surface brightness (P) and surface brightness per unit of Faraday depth F

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

- only positive lambda have physical meaning
- and incomplete sampling in lambda^2

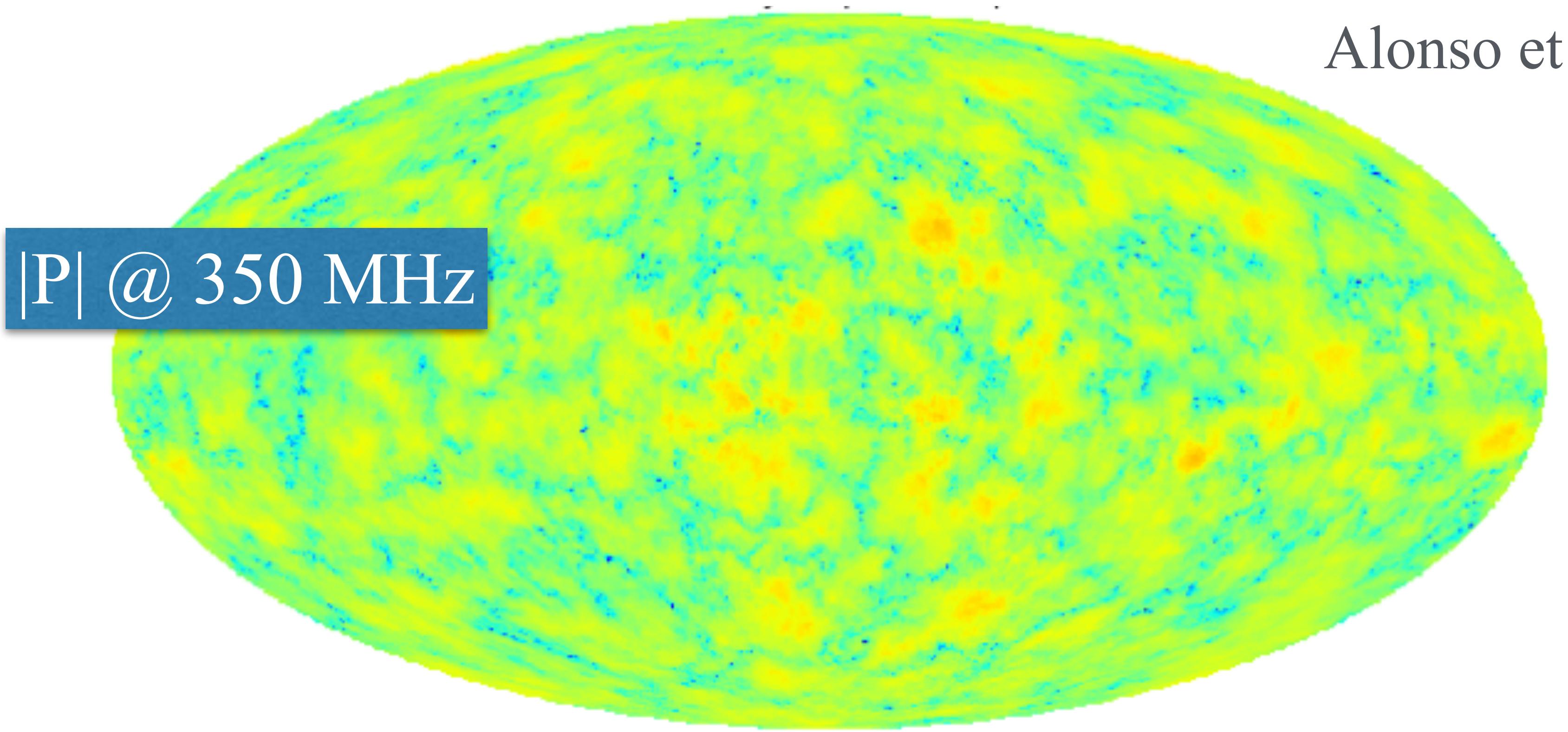
need to define a RM transfer function (RMTF) that gives the resolution in Faraday depth:

FWHM ~ (Delta lambda^2)^-1 total bandwidth

*lack of sensitivity to structures extended in Faraday depth* http://intensitymapping.physics.ox.ac.uk/CRIME.html

# CRIME Synchrotron simulations

Alonso et al 2014




- done in RM space
- tuned on Hammurabi simulations and use RM from *Opperman et al.*

@ EoR frequencies
P simulations are difficult:

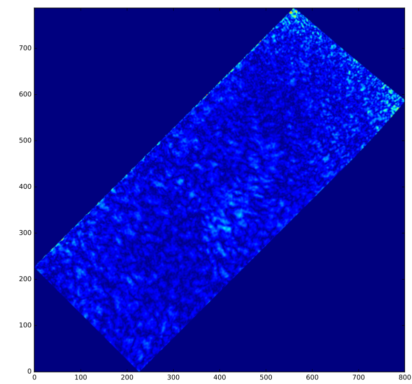
- lack of correlation with total intensity
- ***depolarisation*** effects

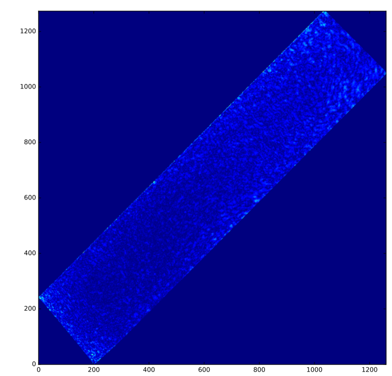
e.g. Burn (1966),
G. Bernardi et al. 2013

using G. Bernardi et al. 2013

# Murchison Widefield Array @ 189 MHz

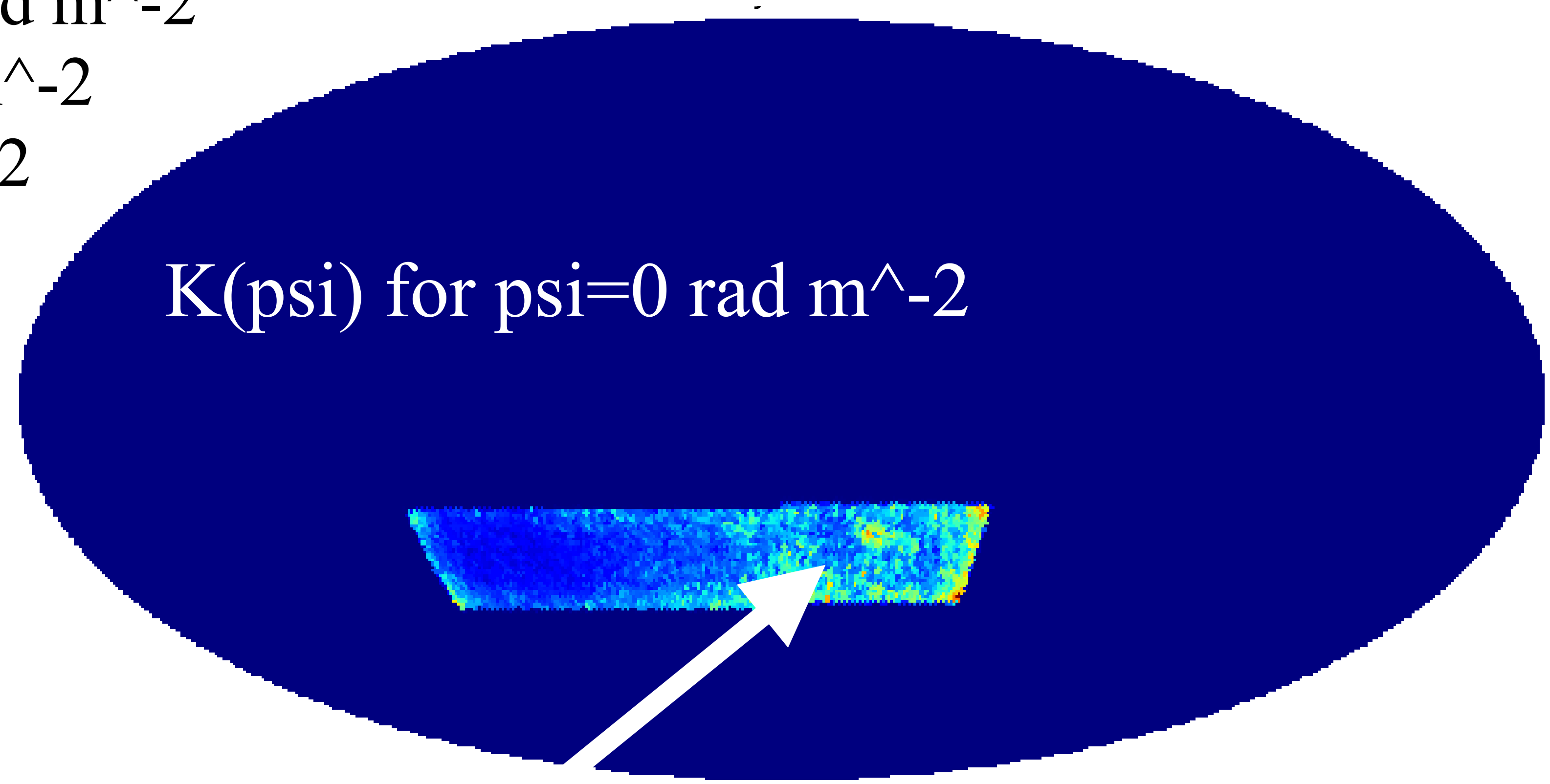
- MWA 32 element 2400 sq degrees
- I, Q, U measurements
- Rotation measure (RM) synthesis





*cube of polarised images at selected faraday depth*

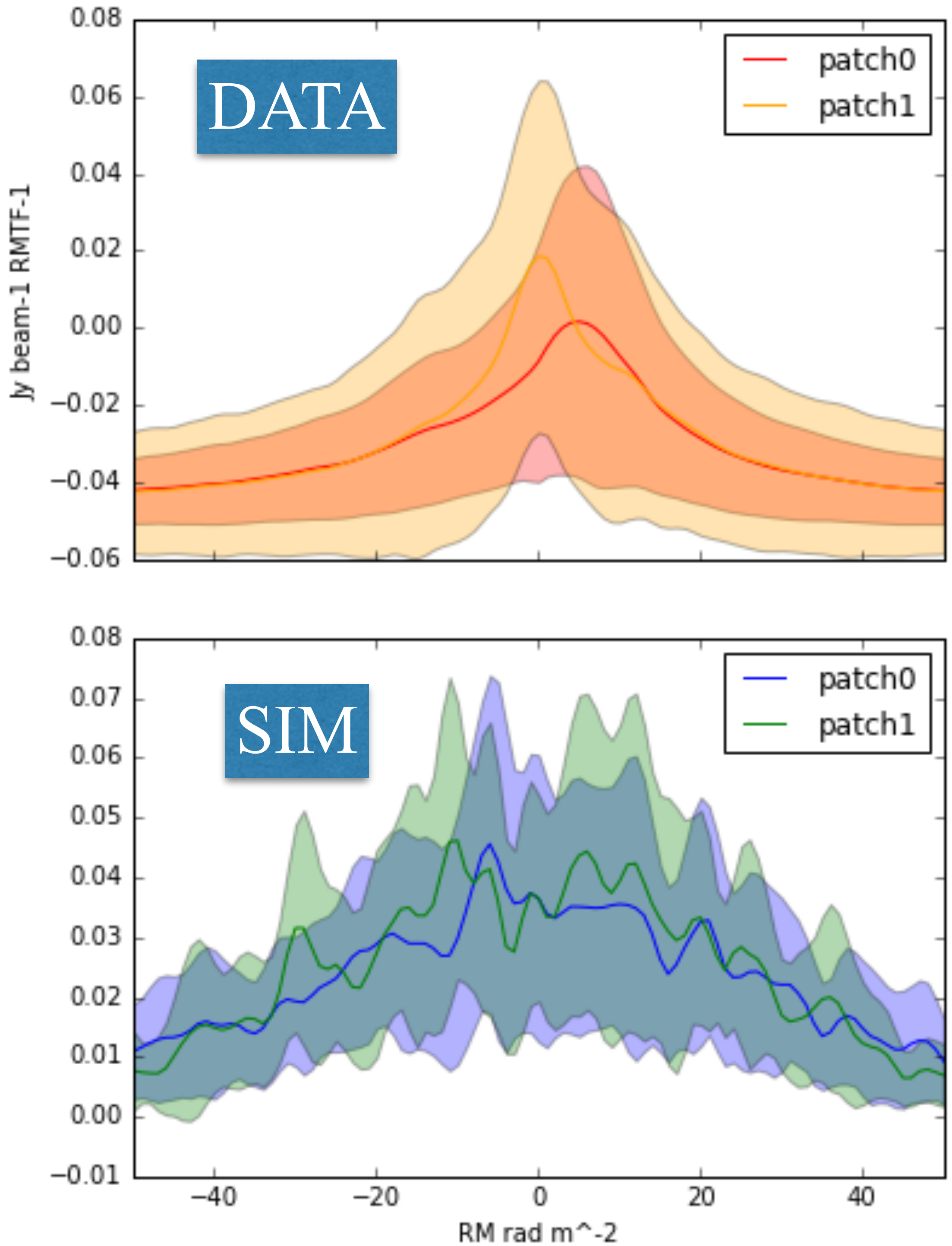
-50 < RM < +50 rad m^-2
in steps of 1 rad m^-2
RMTF 4.3 rad m^-2




- Run MWA-like CRIME sims
- Compare sims and data

structures without total intensity counterpart

# RM-synthesis on CRIME simulations




MWA-like sims:

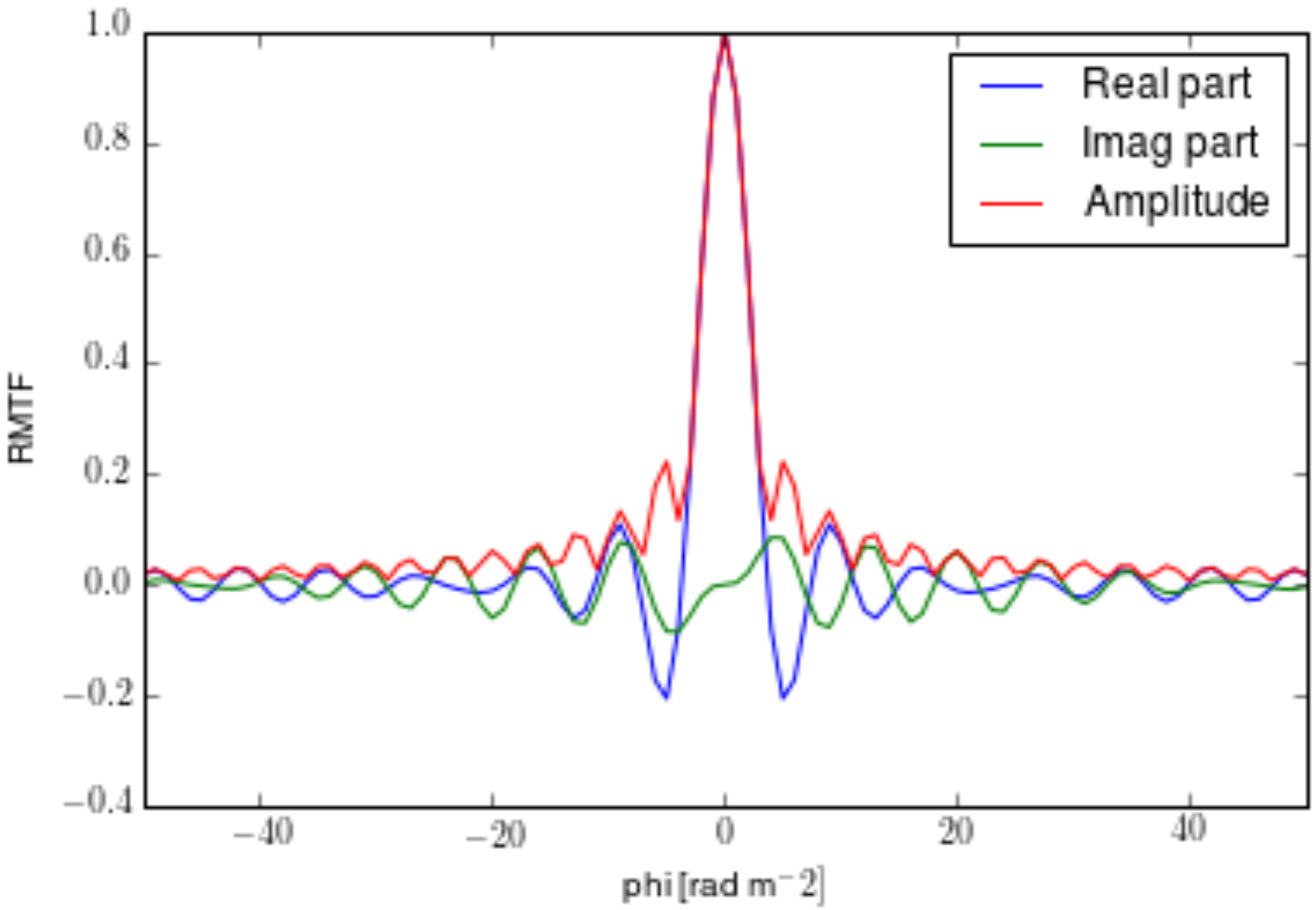
- same frequency range
- same patches in the sky
- same frequency and angular resolution

*Apply on SIM same pipeline of the DATA:*

- RM-synthesis
- RM-CLEAN to remove Side-lobes of RMTF

# RM-synthesis and RM-clean

e.g Bretjens&Bruyn (2005),
Heald, Brown&Edmonds (2009)



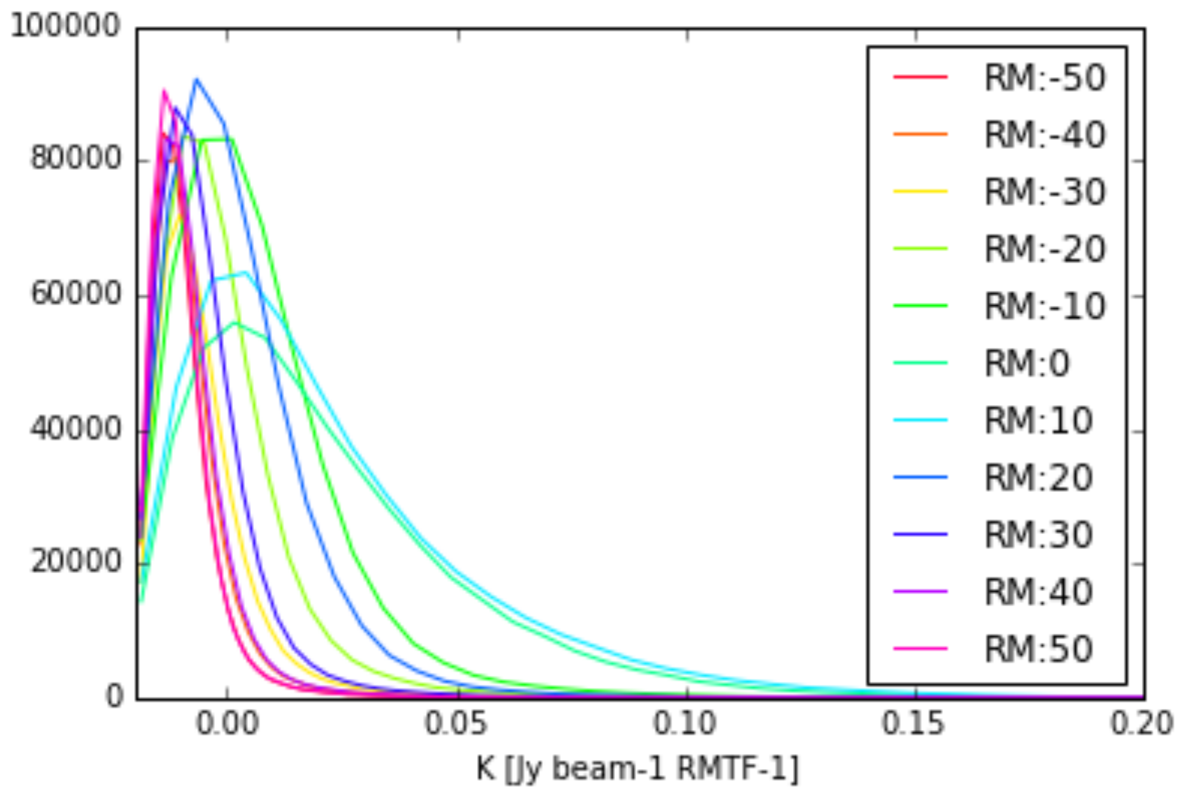

- After RM-synthesis the Faraday cube can be deconvolve from the effect of RMTF
- procedure finds peaks and iterative subtract a scaled version of RMTF

*work in progress*

*Can we say something directly from DATA?*

# MWA data behaviour

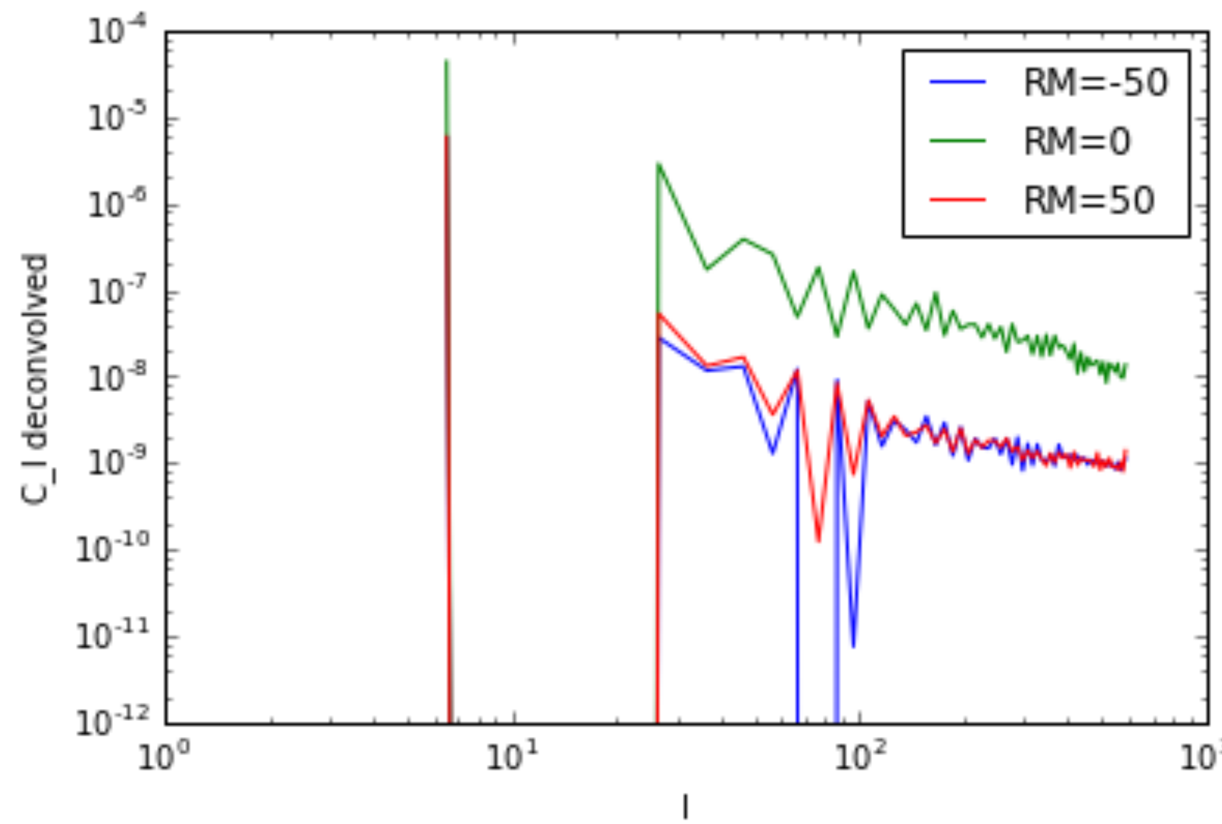
at fixed RM looking at different LOS




- The farthest slices in the cube can be use to <u>estimate the noise level</u>
- At fixed RM the data follow a Rayleigh distribution.

*consequence of the assumption U, Q ~ N(0, sigma)*

- PS reconstruction using *HEALPIX (K.M. Gorski et al., 2005)* and the MASTER algorithm for mask deconvolution *(Hivon et al, 2002)*
- we can model it with a power law

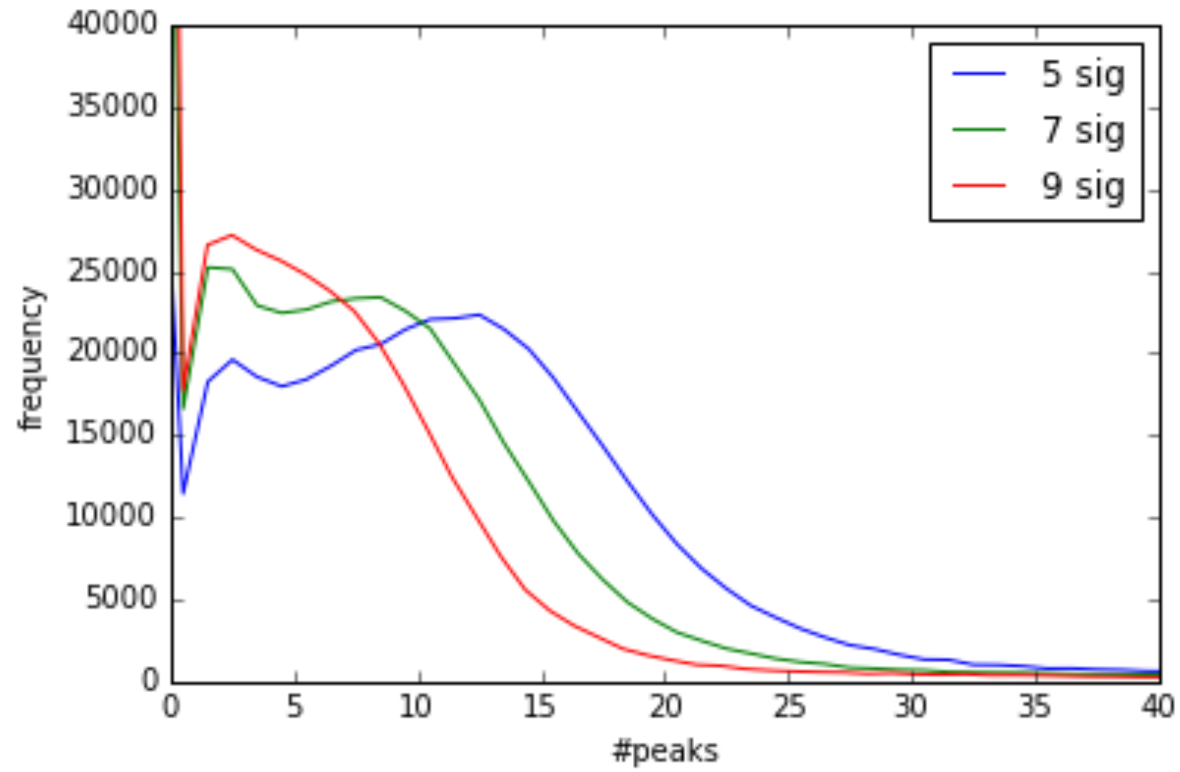


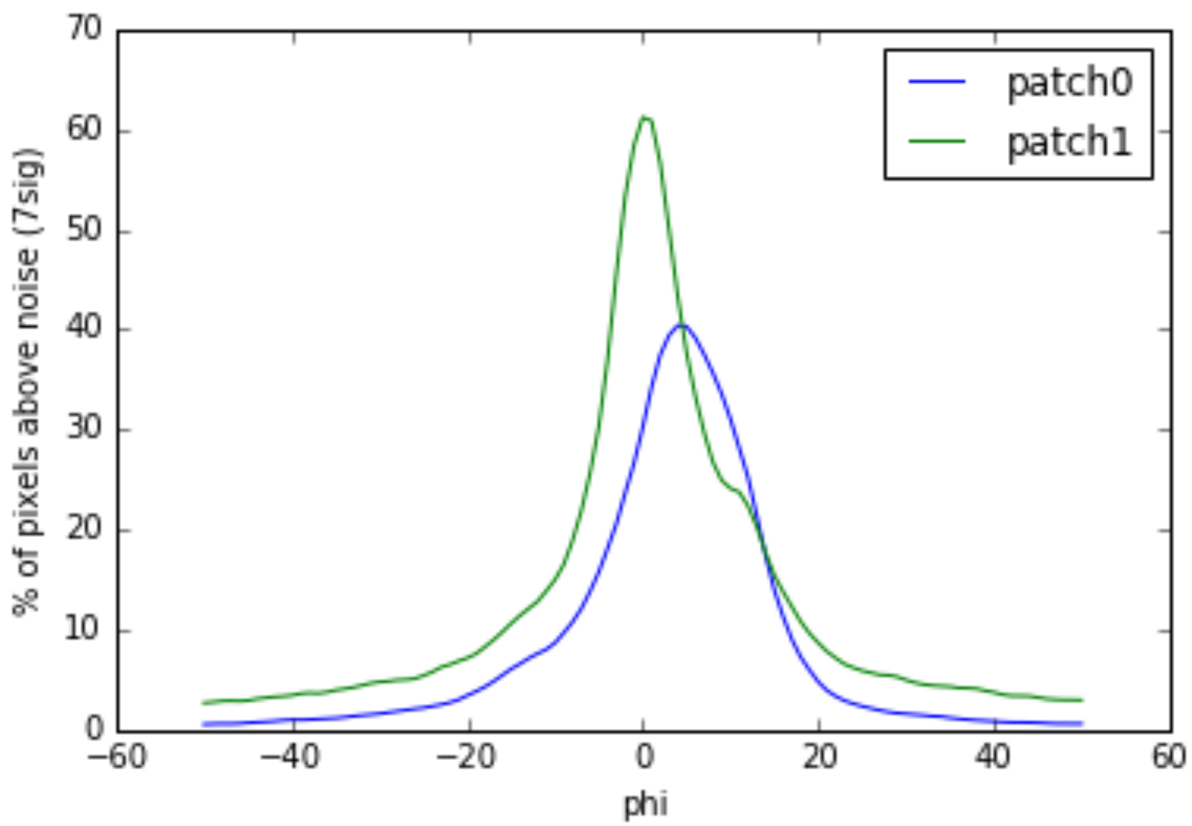
# MWA data behaviour

- study the distribution of pixels above different *sigma noise cutoff* for every LOS

- as a function of RM the % of pixel above threshold
- the signal is concentrated around ~ RM=0

as a function of RM, fixing LOS




- use these properties to generate a RM cube
- Fourier transform back to polarisation intensity P
- compare with (and improve) CRIME simulations (Alonso et al 2014)

# Conclusions

- Polarized synchrotron can in principle be a challenge for component separation techniques
- Simulations @ low frequency (where EoR is) can not be tuned on higher frequency data or unpolarised synchrotron emission

With CRIME simulations:

- generate Q and U full sky maps as close as possible to MWA data
- apply RM analysis to them (and cleaning)
- check statistical behaviour
- change CRIME to fit MWA?

With MWA data:

- find a statistical behaviour for K(psi)
- describe the distribution of peaks
- Can we extend it full sky?