Max-Planck-Institut für Radioastronomie

INSTITUTE OF CONTINUOUS MEDIA MECHANICS

Statistical properties of polarized radio continuum emission and effects of data processing

I.Mizeva,
R.Beck, P.Frick, W.Reich, D.Sokoloff

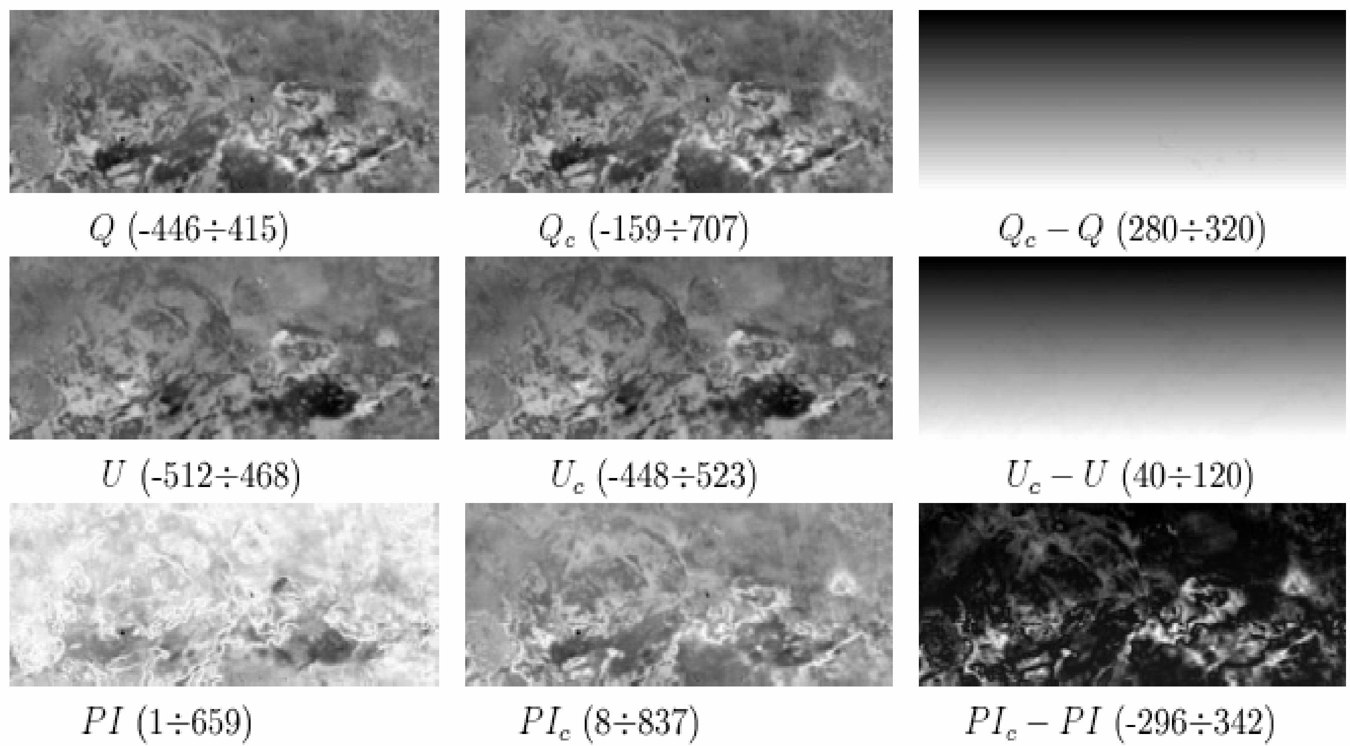
- Motivation
- Data selection:
  - Anti-centered;
  - Galactic plane;
  - High latitude
- Small-scales structure characteristics:
  - Probability distribution function
  - Spectra
- Data preprocessing procedures and their influence on statistical characteristics
  - Absolute calibration
  - Source subtraction
  - “Denoising”
- Conclusions

Motivation

- ISM-turbulence is MHD turbulence
- Statistics of B is required as well as statistics of U, P, etc.
- No direct measurements for B, the information comes from PI
- PI is a nonlinear combination of Stockes parameters Q and U
- Q and U maps require some pre-processing (calibration, sources subtraction, bias correction)
- WHAT IS HAPPENED THEN WITH statistical characteristics of PI ?

$$PI = \sqrt{Q^2 + U^2}$$

Galactic plane data

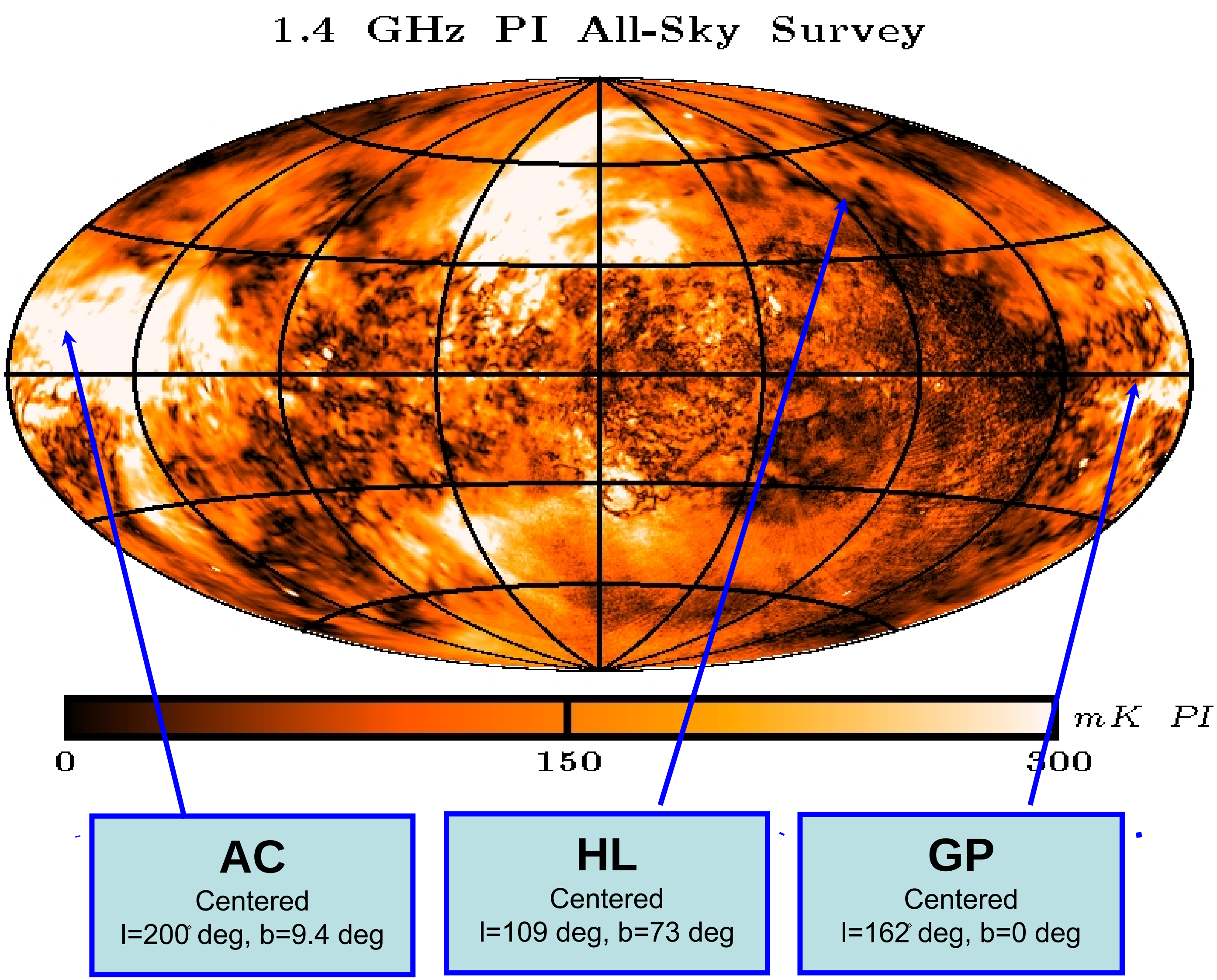


Centered l=162 deg, b=0 deg, Map area (361*136) pix, (1440*540) arcmin.

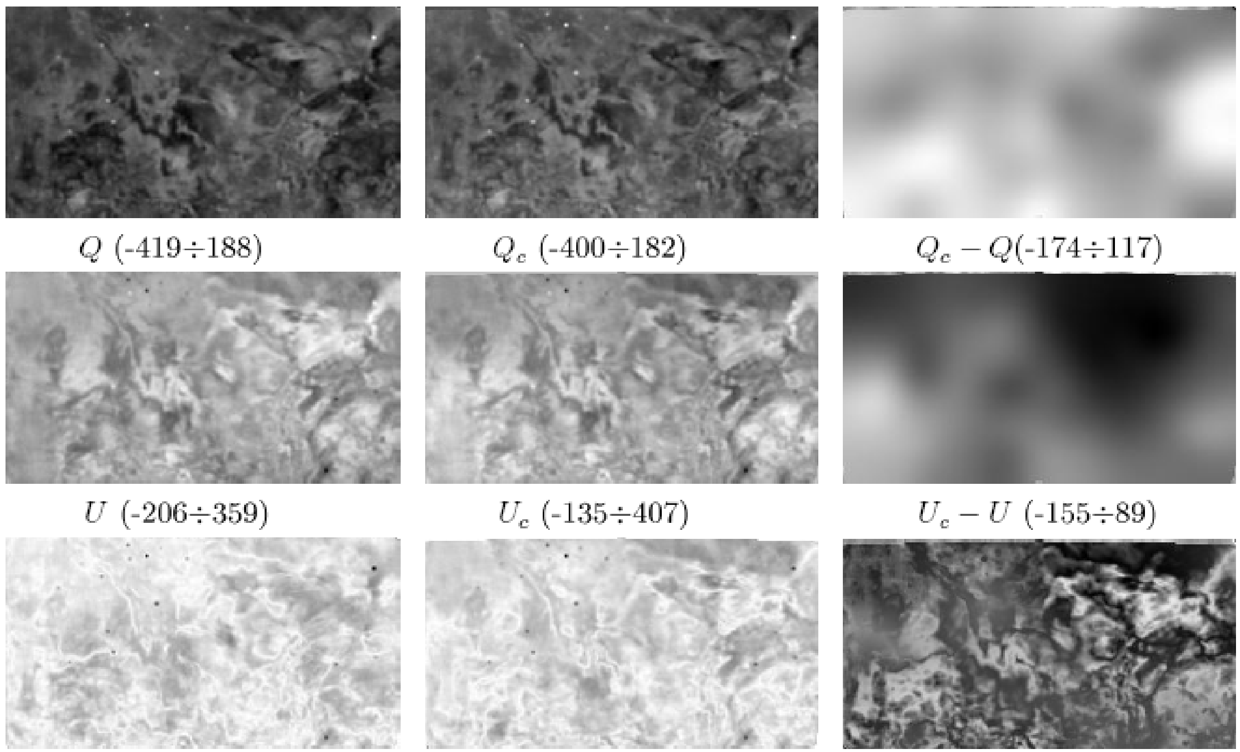
3 sets of data were used:
-anti-centered field (AC),
-data in the galactic plane (GP),
-high latitude data (HL)

Map center l, b (deg)	Map area (pix)	Map area (arcmin)	Reference
AC(200,9.4)	301×169	1200 × 672	Uyaniker et al. 1999
GP(162,0)	361×136	1440 × 540	Reich et al. 2004
HL(109,73)	76×76	300 × 300	Reich et al. 2002

- Based on observations with the 100-m telescope of MPIFR (Max-Planck-Institut fur Radioastronomie) at Effelsberg at 1.4GHz


1.4 GHz PI All-Sky Survey
mK PI
0
150
300
AC
Centered
l=200 deg, b=9.4 deg
HL
Centered
l=109 deg, b=73 deg
GP
Centered
l=162 deg, b=0 deg

Anti-center data



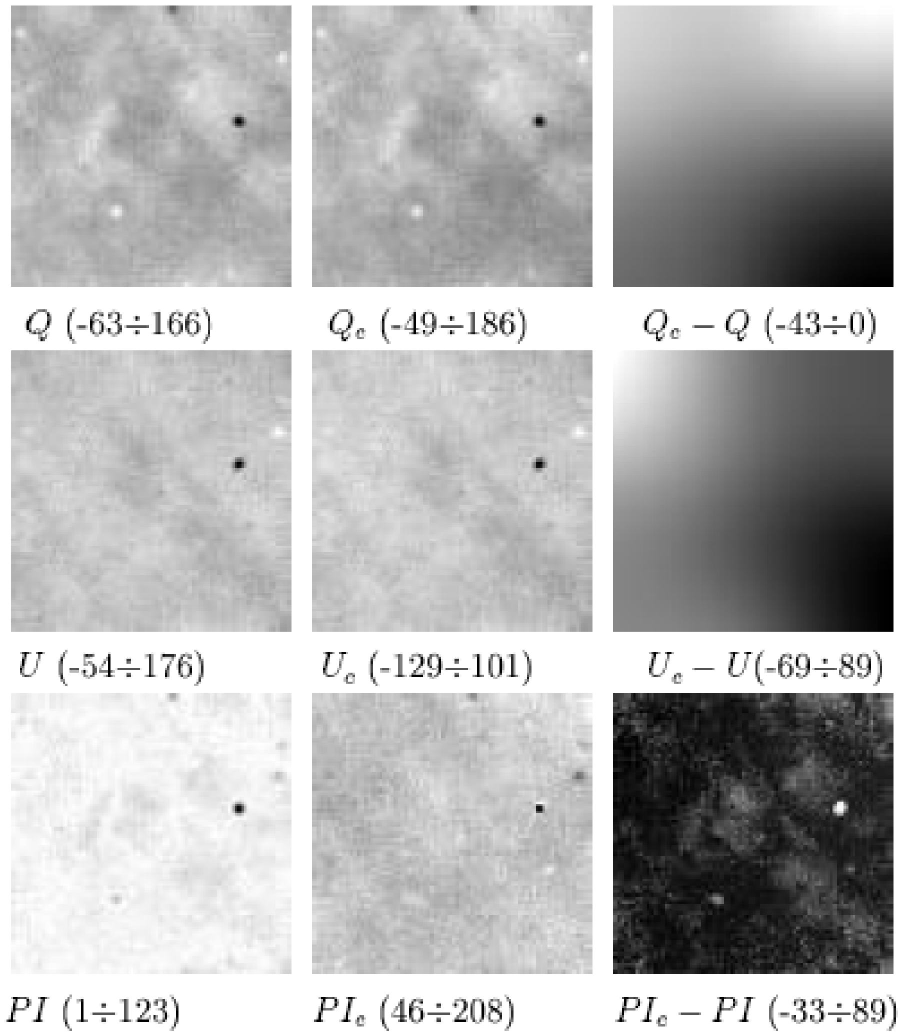
Q (-419÷188) Q_c (-400÷182) $Q_c - Q$(-174÷117)

U (-206÷359) U_c (-135÷407) $U_c - U$ (-155÷89)

PI (0÷466) PI_c (0÷540) $PI_c - PI$ (-175÷153)

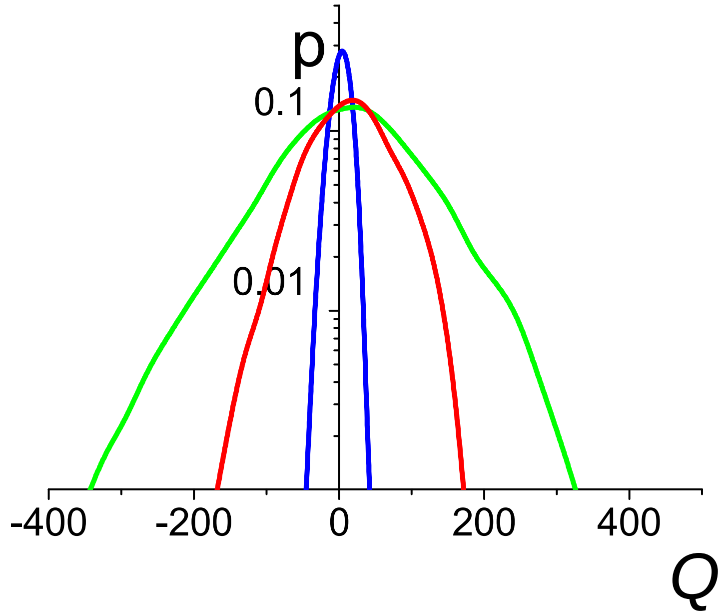
Centered l=200° deg, b=9.4 deg, Map area (301*169) pix, (1200*672) arcmin.

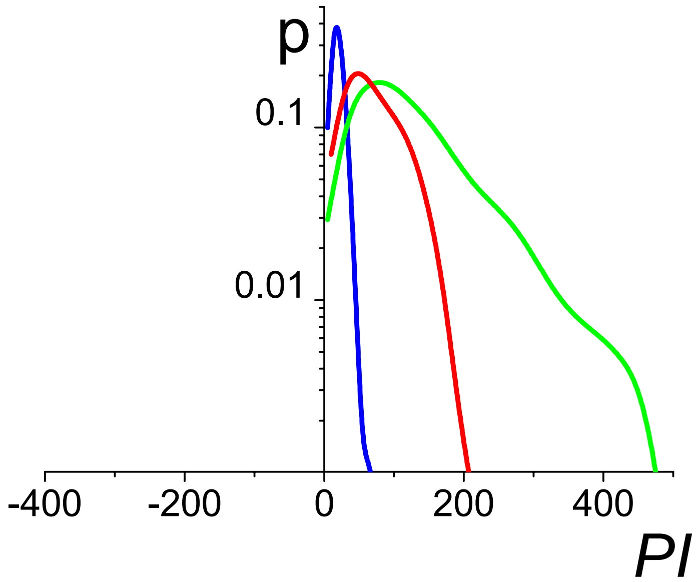
High latitude data

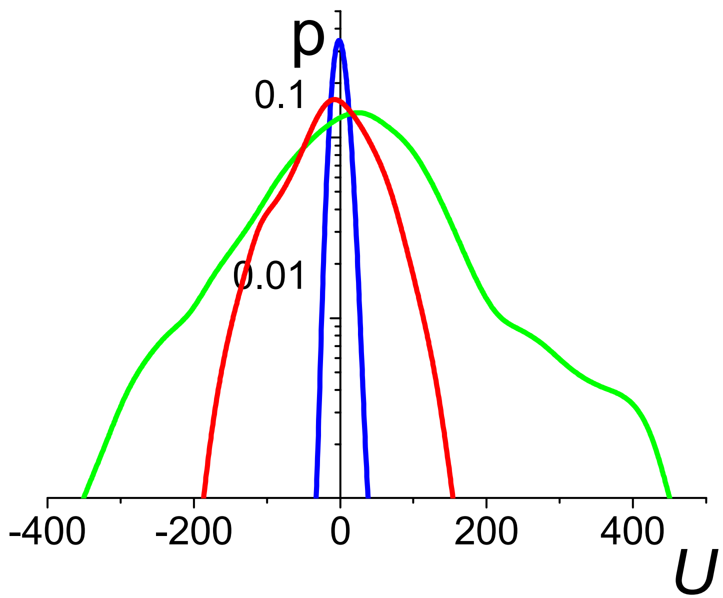


Centered l=109 deg, b=73 deg, Map area (76*76) pix, (300*300) arcmin.

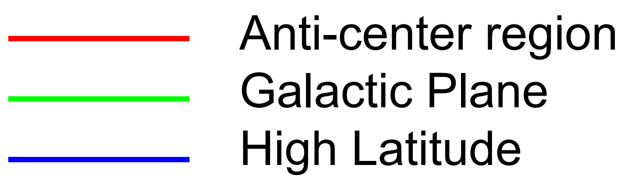
Probability distribution function of original data



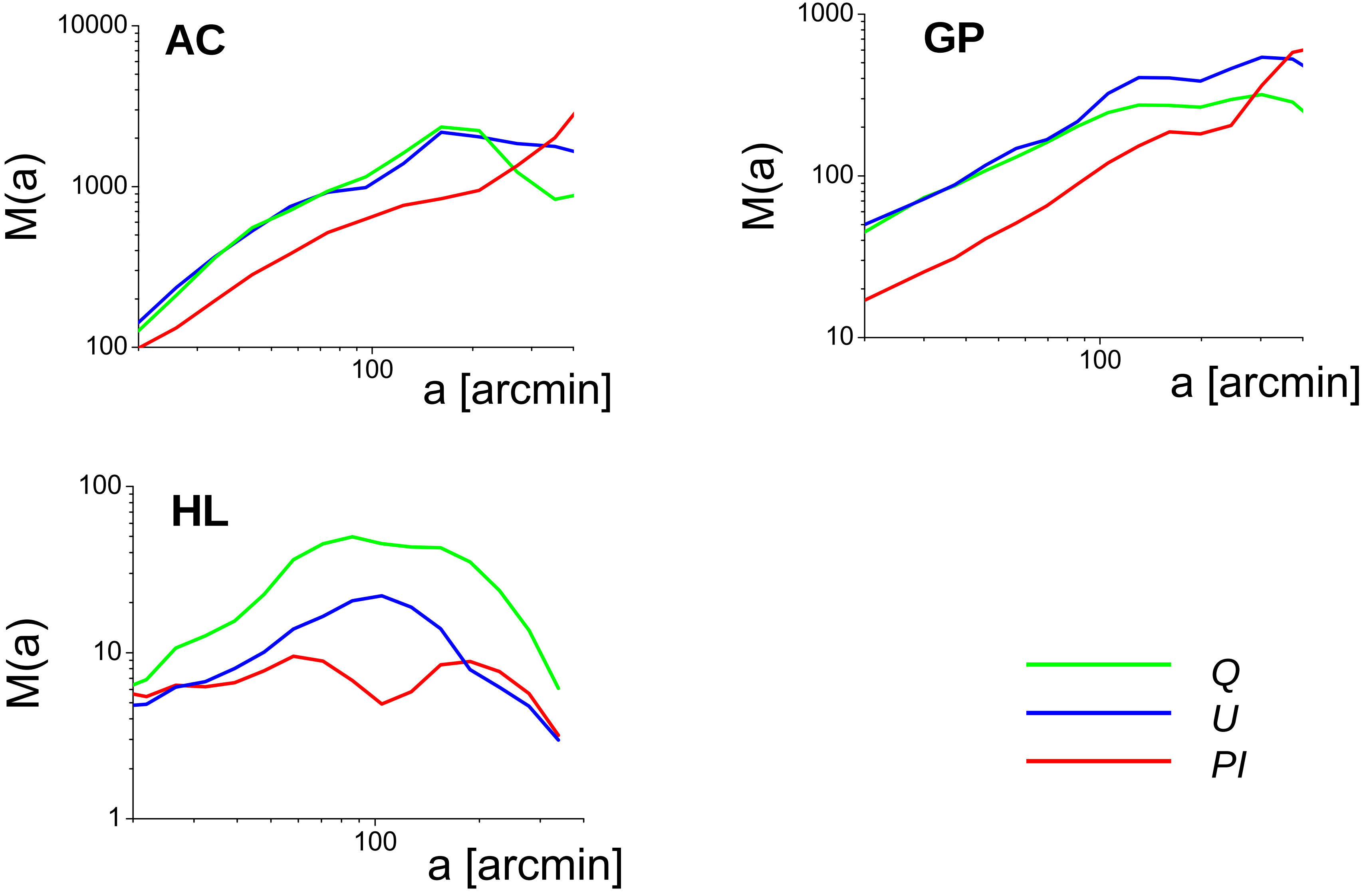




$$PI = \sqrt{Q^2 + U^2}$$

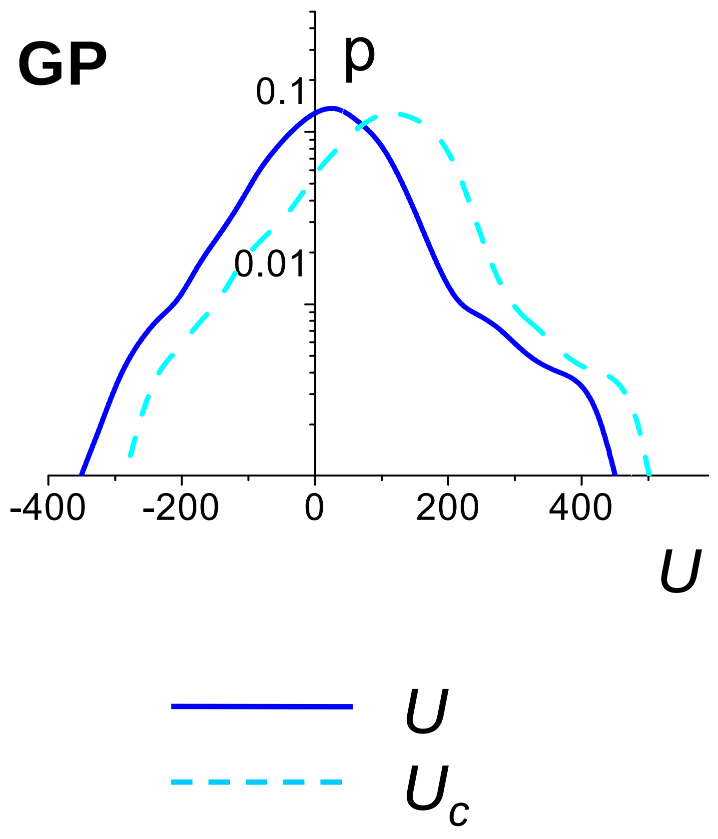


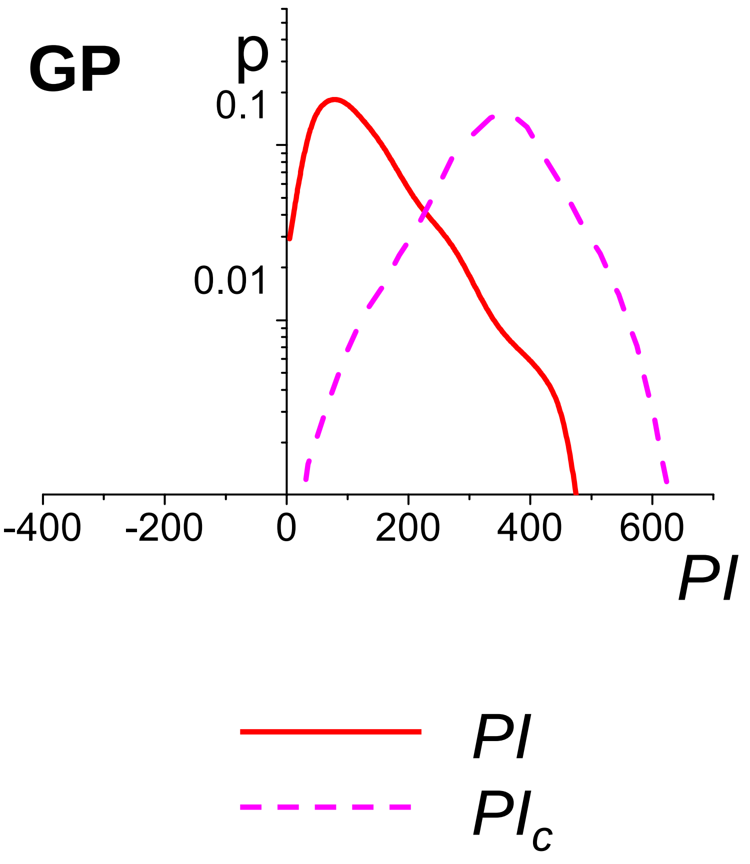
Spectra of original data



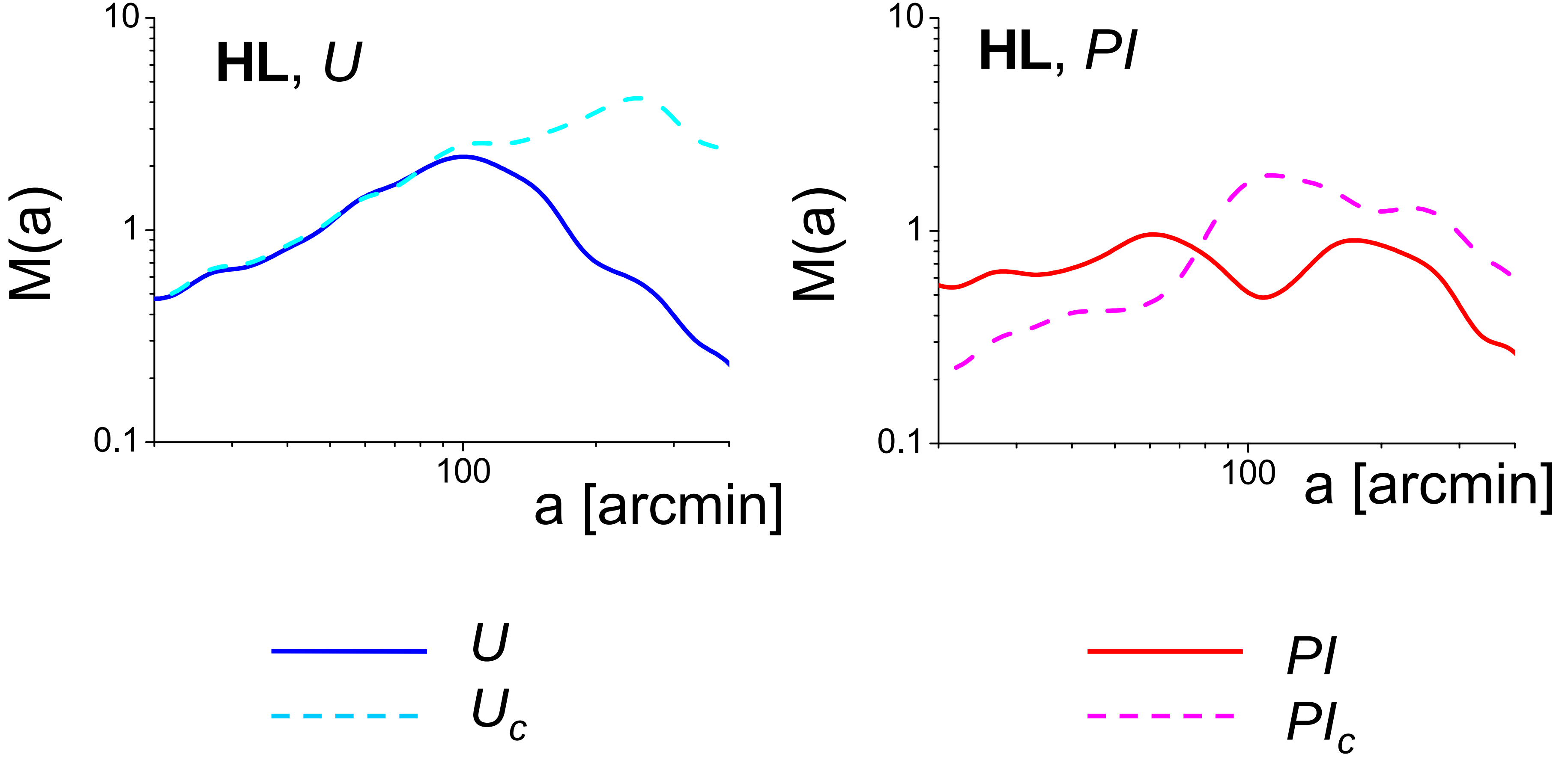
Effect of absolute calibration on p.d.f

Absolute calibration
– adding missing large scales from other observations (sometimes modeling)



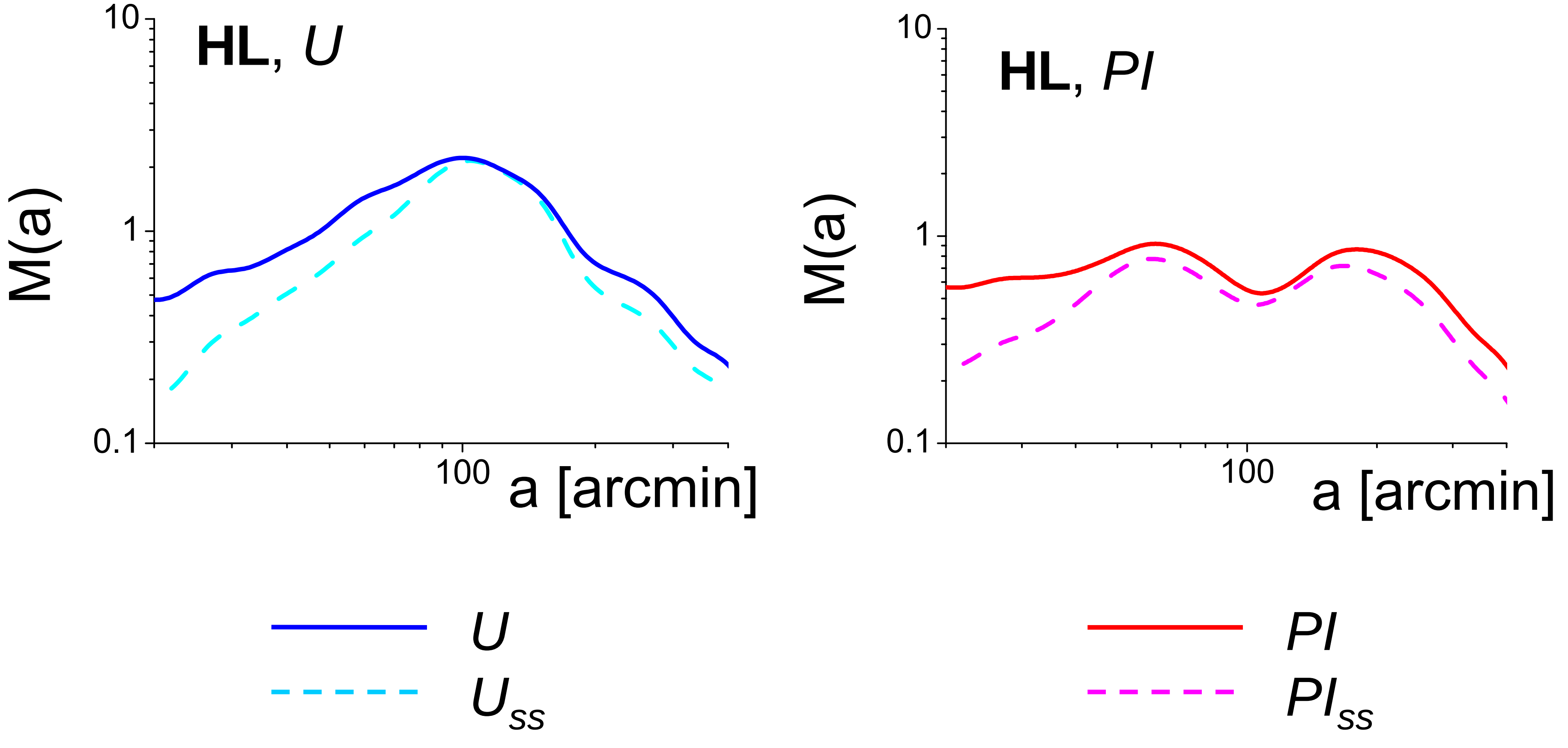


Effect of absolute calibration on spectra



Effect of source subtraction on spectra

Source subtraction
– removing discrete radio sources



“Denoising”

– the aim is to restore the Gaussian nature of noise (as in measured Stokes parameters Q and U) in PI which has asymmetric Rice distribution. In practice it is a positive bias correction:

$$PI_d^2 = (Q_s - C_Q)^2 + (U_s - C_U)^2 - \xi^2$$

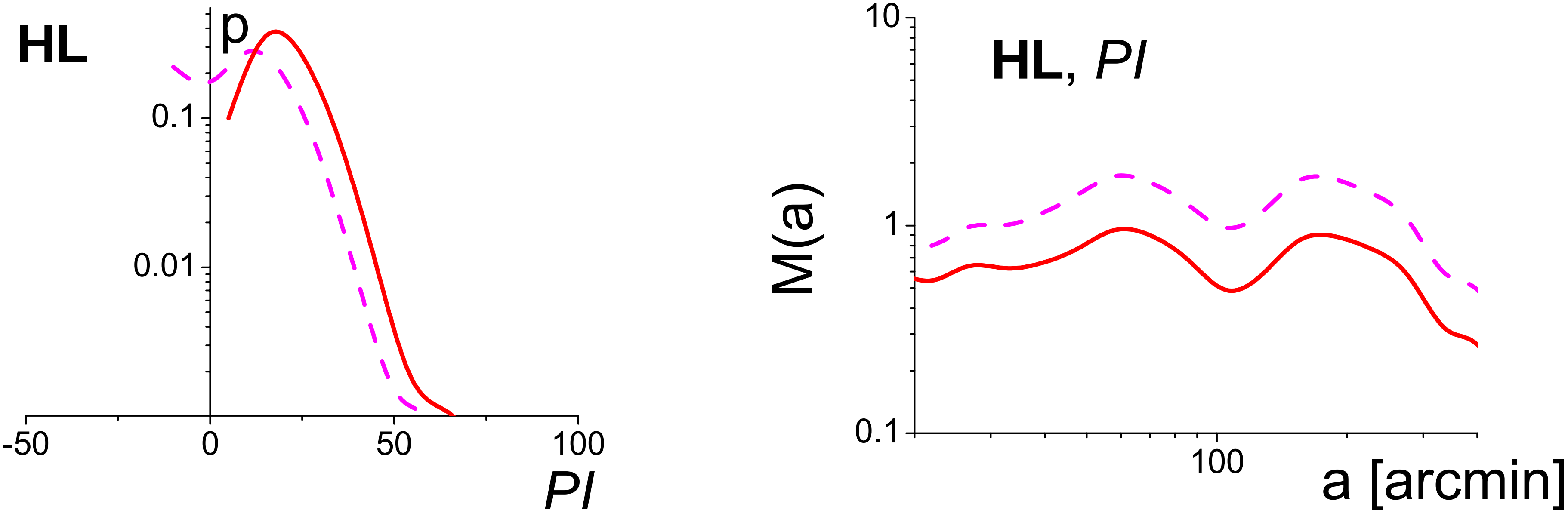
In case

$$(Q_s - C_Q)^2 + (U_s - C_U)^2 < \xi^2$$

PI_d is formally defined as

$$PI_d^2 = -\sqrt{\left|(Q_s - C_Q)^2 + (U_s - C_U)^2 - \xi^2\right|}$$

Effect of denoising on spectra and p.d.f.

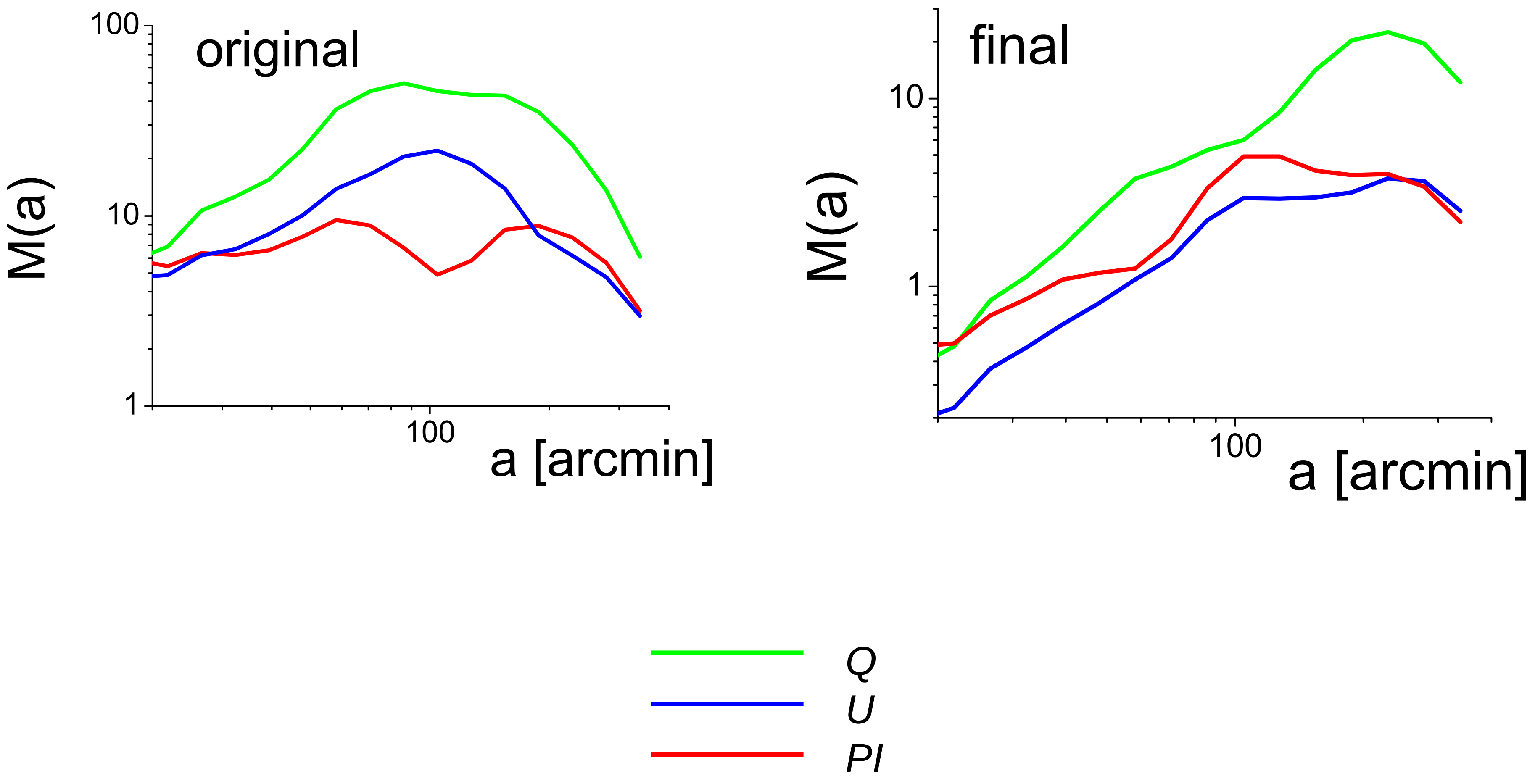


PI

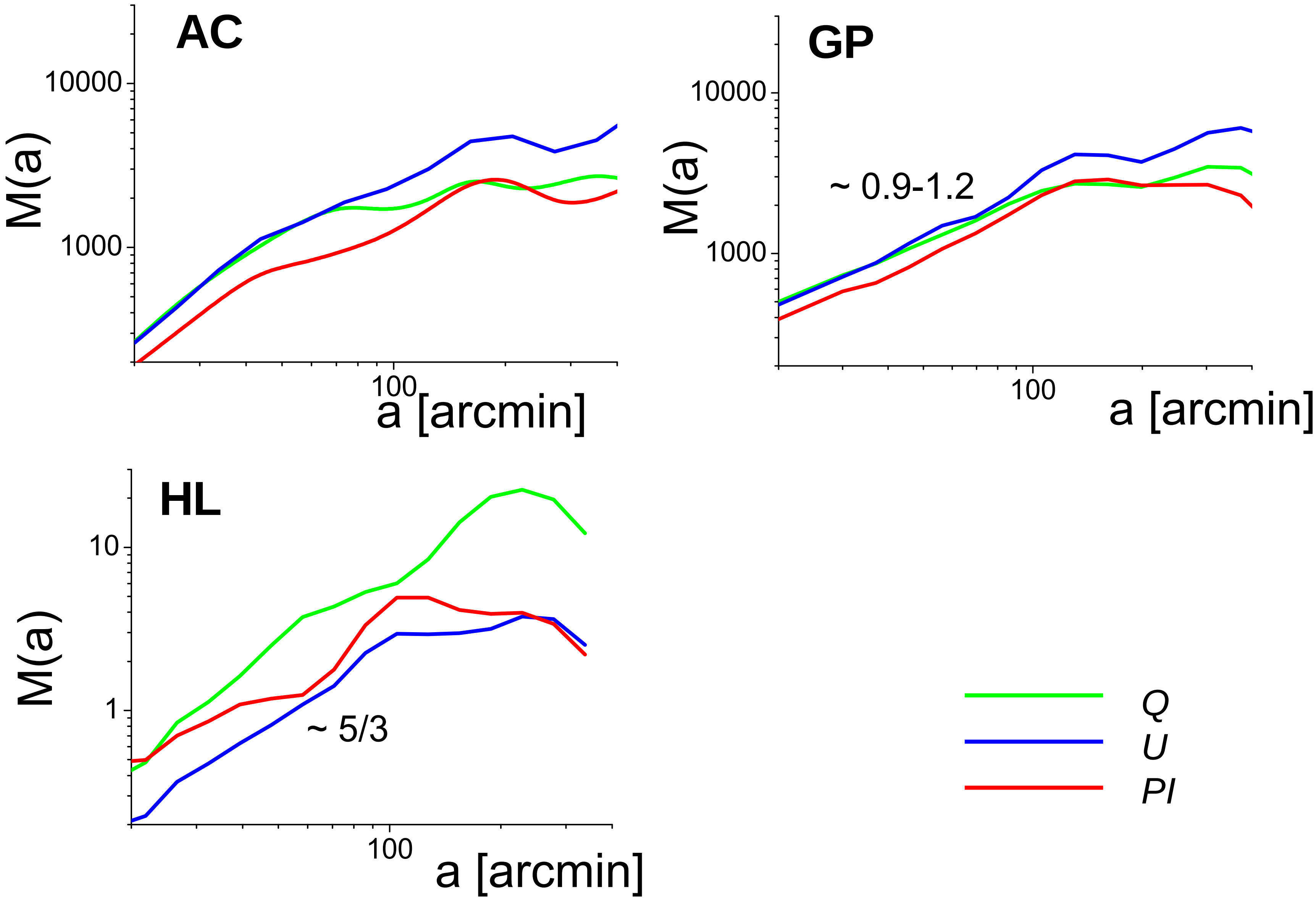
PI_d

“DENOISING” -> “DEBIASING”

Original and final spectra for HL map

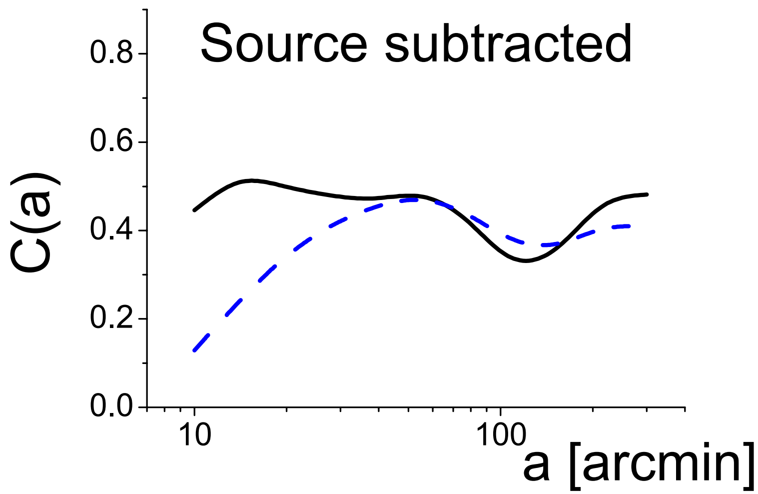


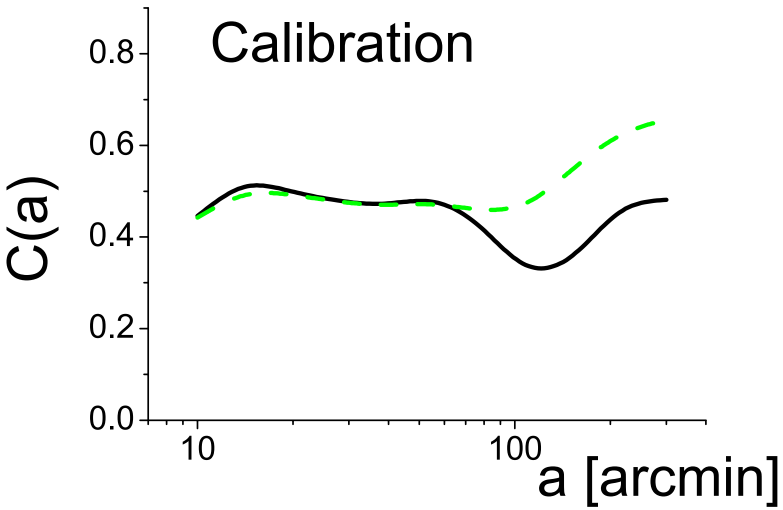
Spectra for 3 regions

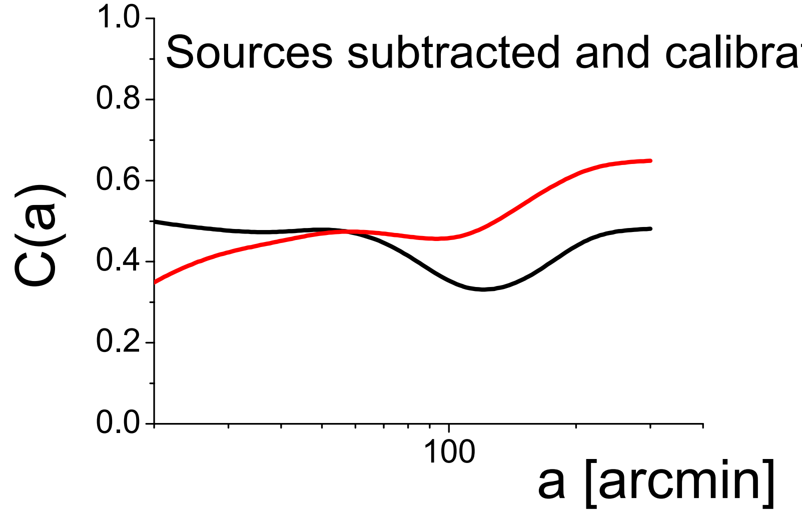


Cross correlation of Stokes parameters

for HL data







Conclusions

- Effects of various procedures were discussed:
  - Calibration affects mainly the large scale structure of emission
  - Source subtraction mainly changes small-scale structure part of specrtra
  - “denoising” does not vary the spectral energy distribution, but may change the entire energy level
  - All together these procedures change spectrum in the whole range of scales

- The spectra obtained contain power-law like ranges at small scales. But direct identification of the slope is misleading, because Q and U spectra do not reproduce the turbulent spectra in a straightforward way. To interprete slope of spectra of Stokes parameters one need simulation of artificial random magnetic field in 3D cube.