Neural network for improving the flux density estimations in polarization of compact sources

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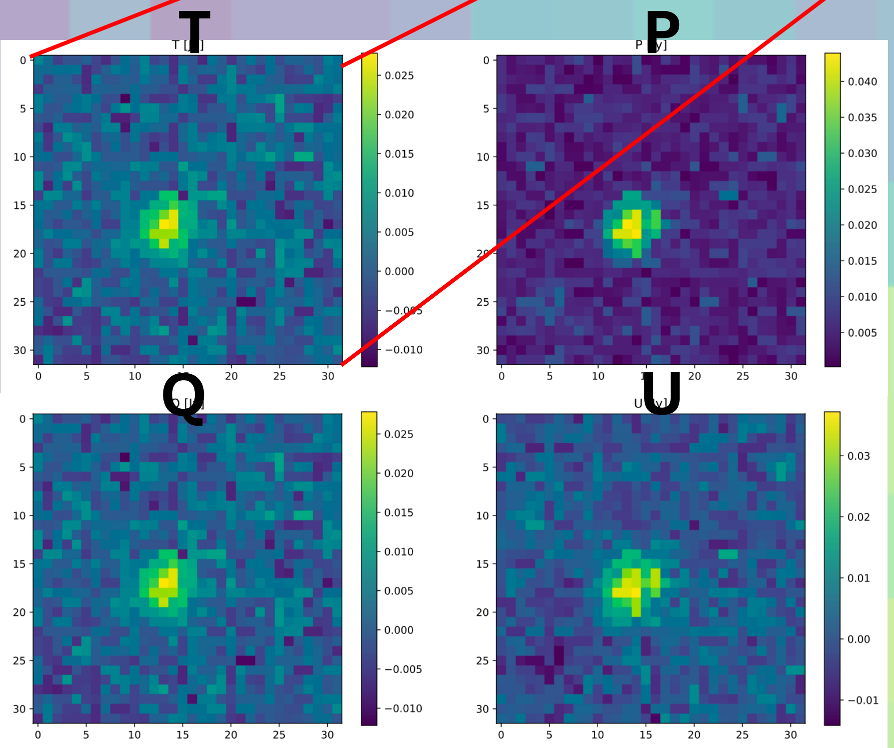
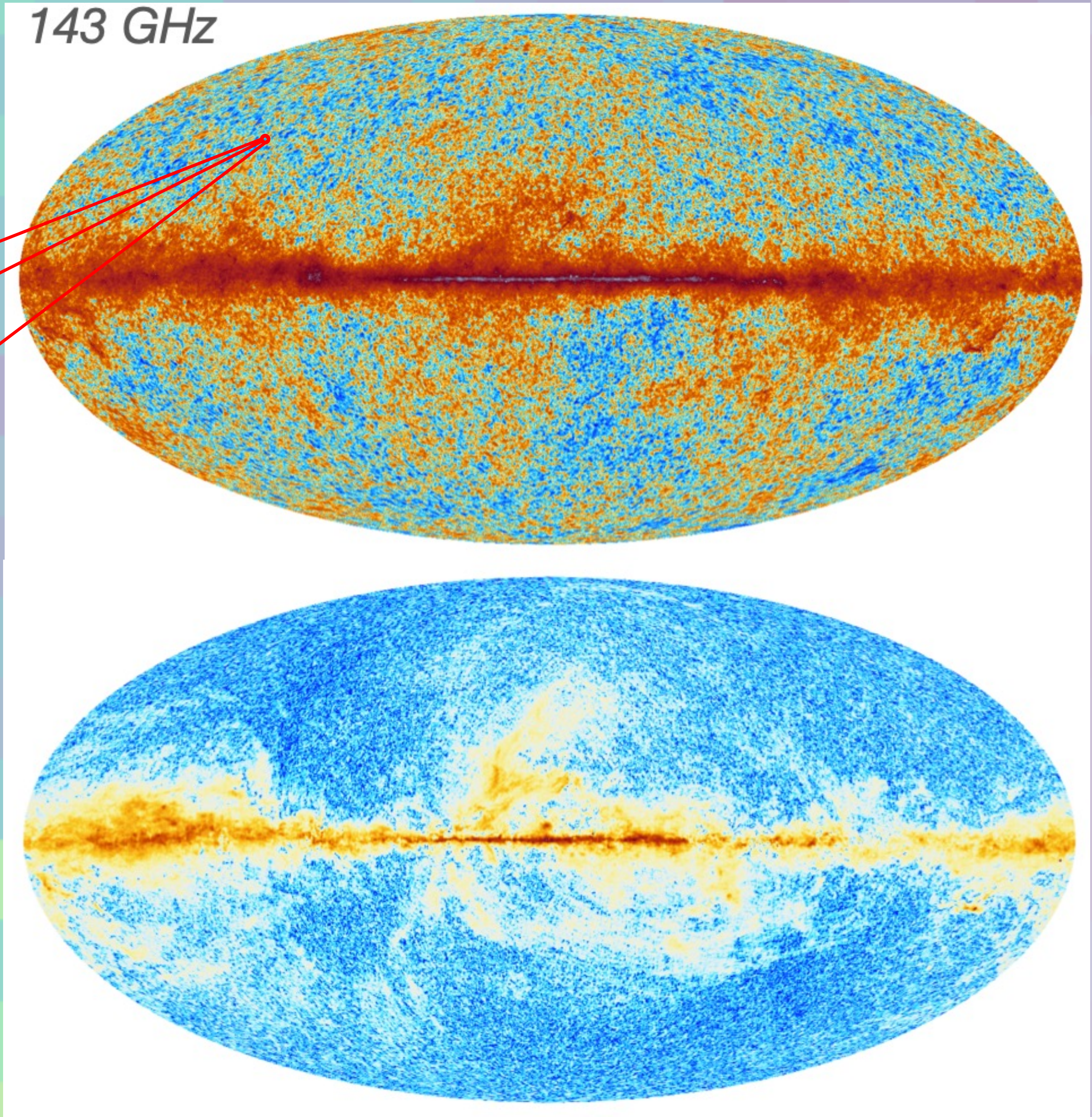
Point Sources

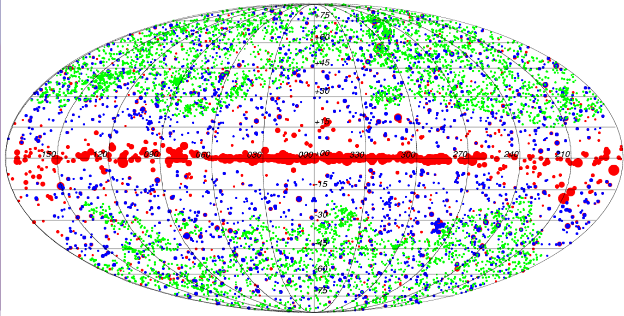
- ➢ Distant galaxies seen as point-like objects through the observational beam





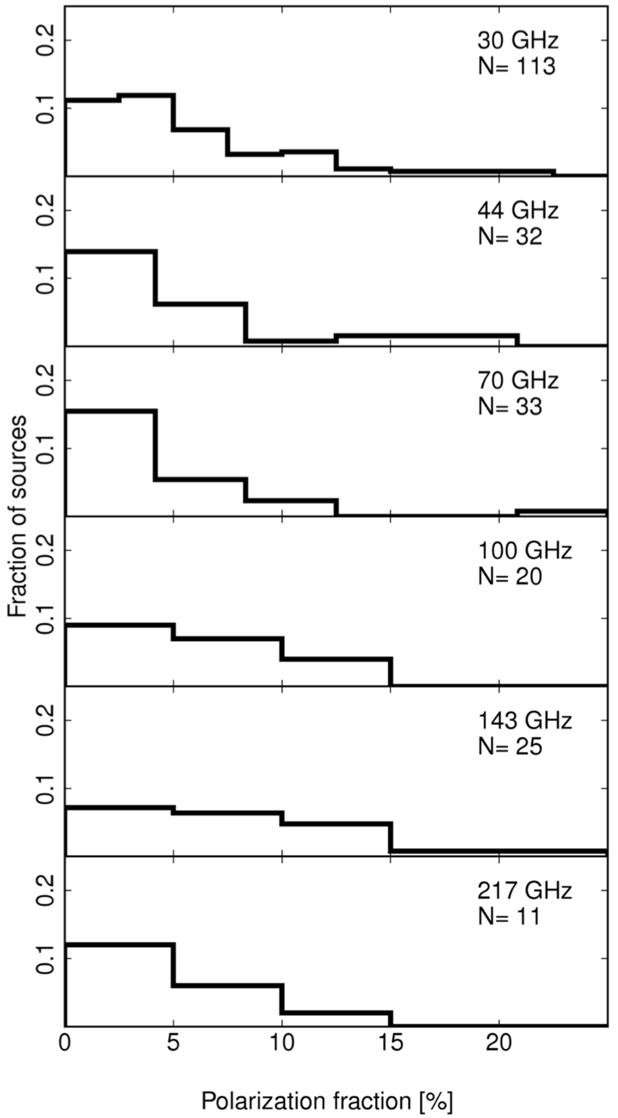
Point Sources

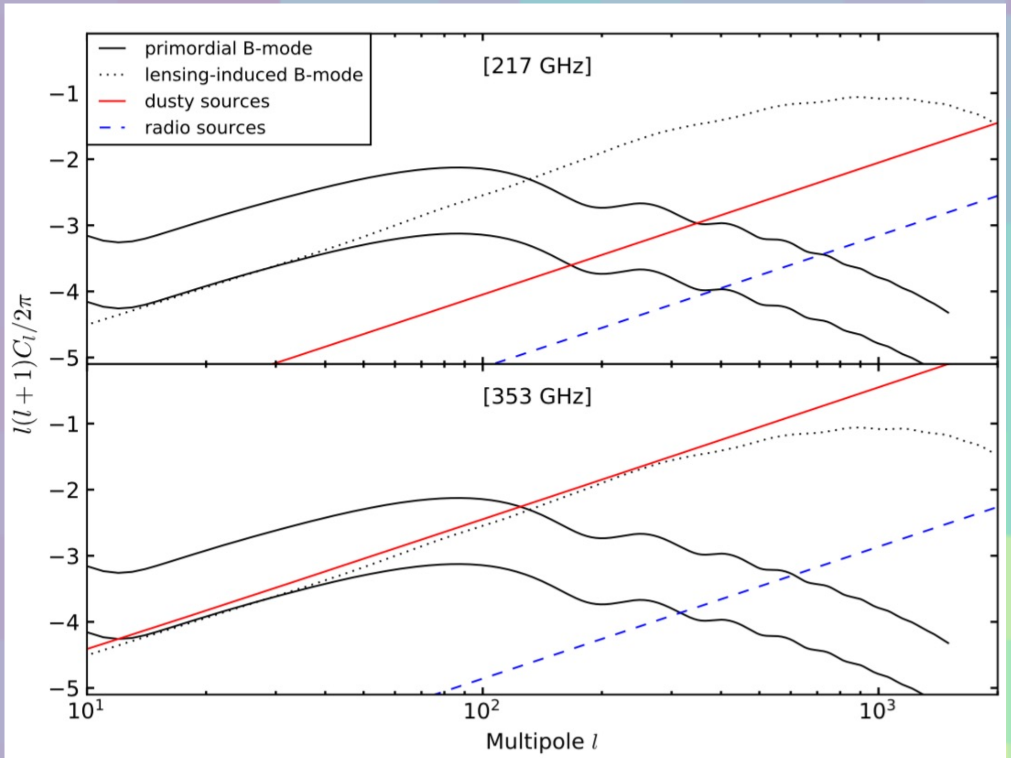
- ➢ Astrophysical interest
- ➢ Contaminant to CMB recovery (removing or mask)



Planck 2015 XXVI

Channel	Flux density 90% completeness [mJy]	No. of	Polariz
		PCCS2	PCCS2
30	427	1560	122
44	692	934	30
70	501	1296	34
100	269	1742	20
143	177	2160	25
217	152	2135	11
353	304	1344	1
545	555	1694	...
857	791	4891	...





Bonavera+17b

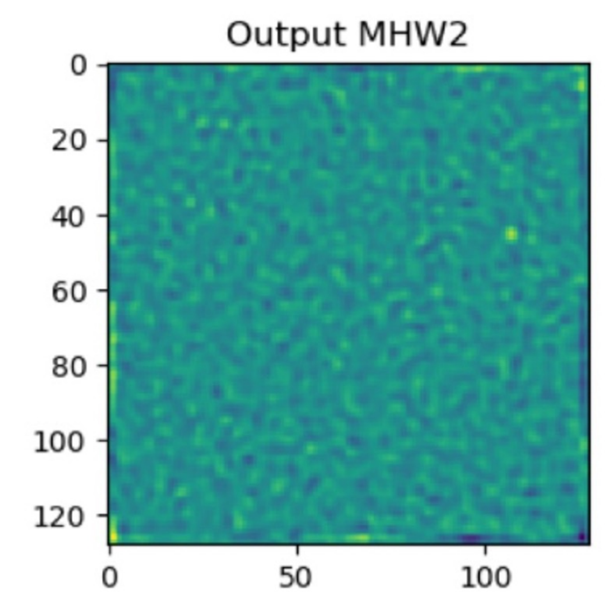
Neural Network approach

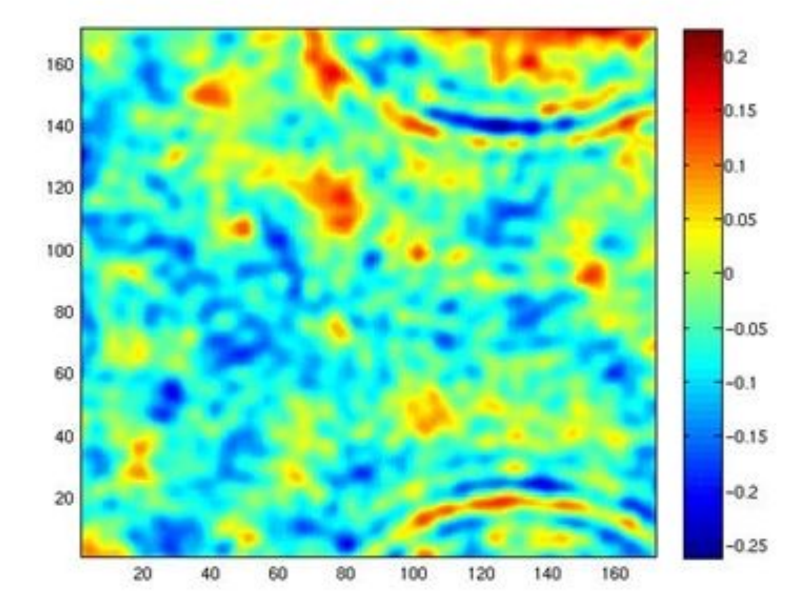
Looking for:

- Better performance
- No ringing
- No border effect
- No bk power spectrum estimation
- More flexible and automatic

Realistic simulations needed:

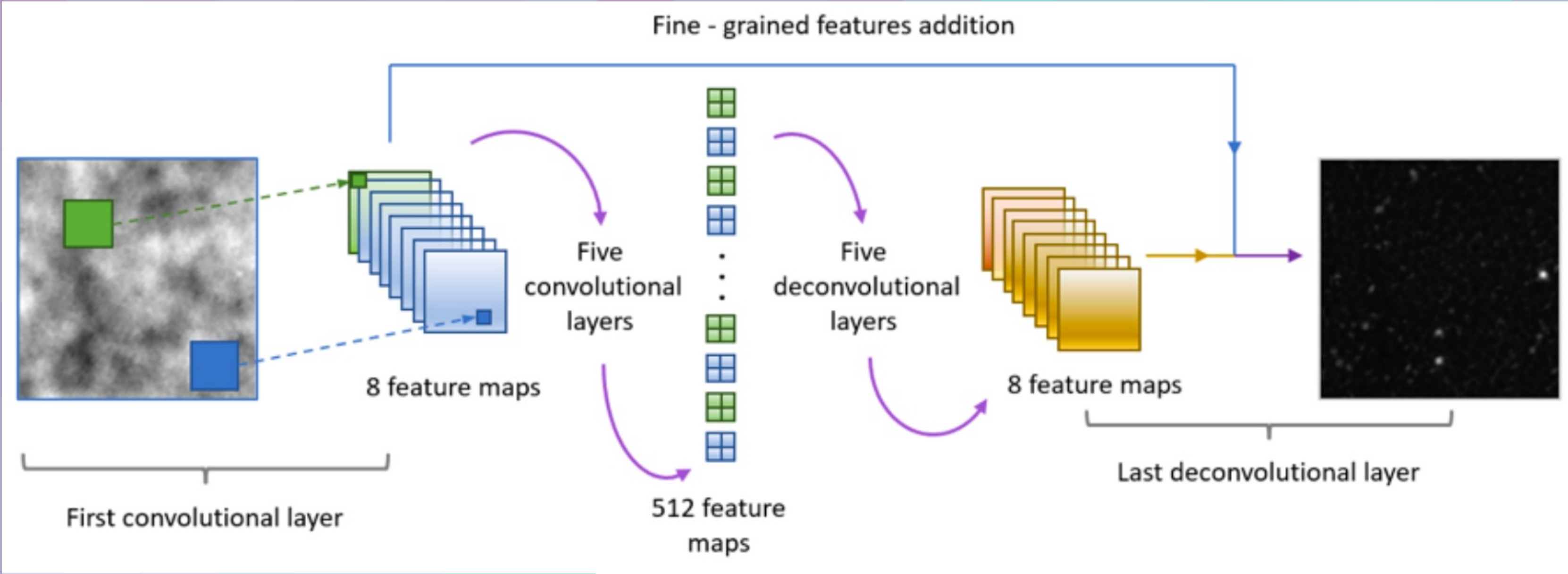
- Patches of the sky
- CMB signal
- Galactic thermal dust and synchrotron emission
- PS radio (label) and IR background
- Instrumental white noise





PoSeIDoN - **Po**int **S**ource **I**mage **D**etecti**o**n **N**etwork

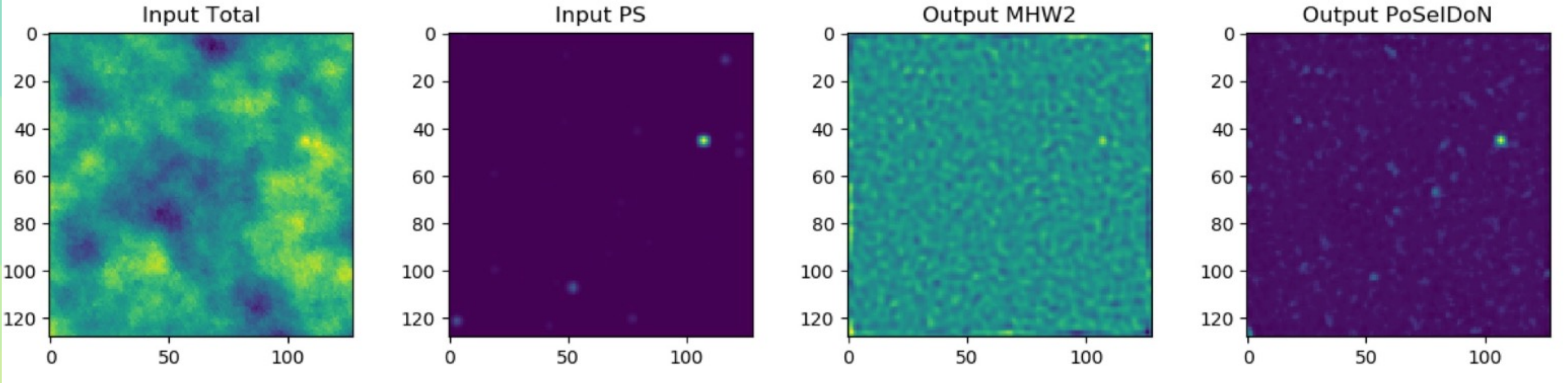
Bonavera+21



6 conv layers:
8-16-64-128-256-512 feature maps
6 deconv layers:
256-128-64-16-8-1 feature maps
Paddding Same, Leaky ReLU,
MSEloss, 50 epochs, ...
Simulations @217 GHz128 x 128 pix
50 000 training set (total & PS)
5 000 validation set

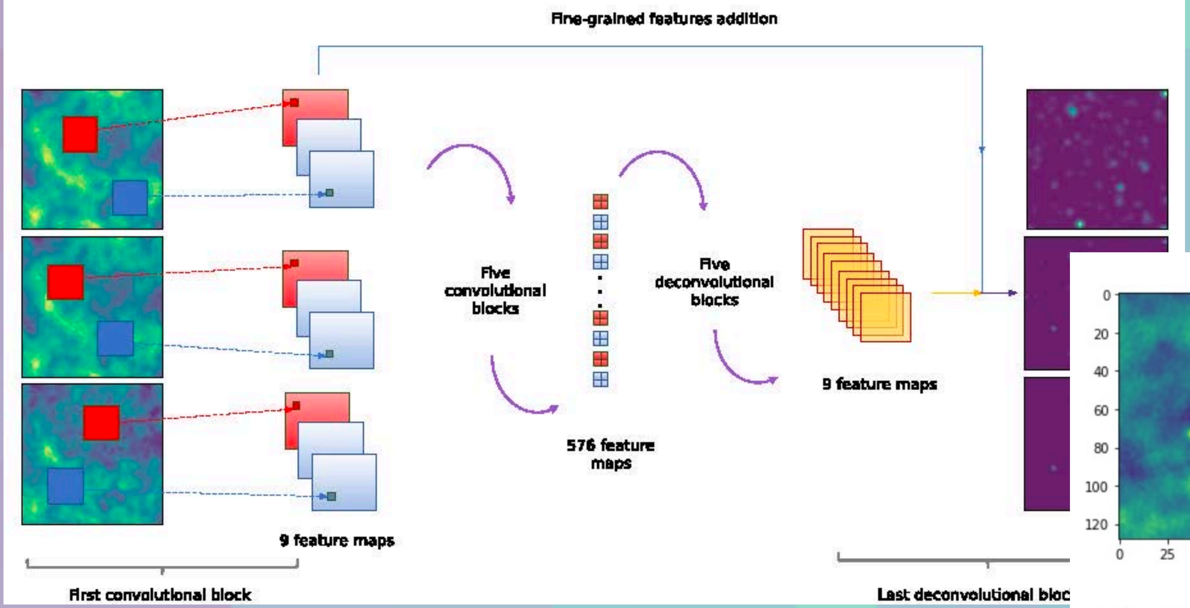
Catalogue:
searching peaks
(i.e. local maxima)

- above σ_{MHW2} intensity threshold (PoSeIDoN)
- above 4 σ_{MHW2} (MHW2)



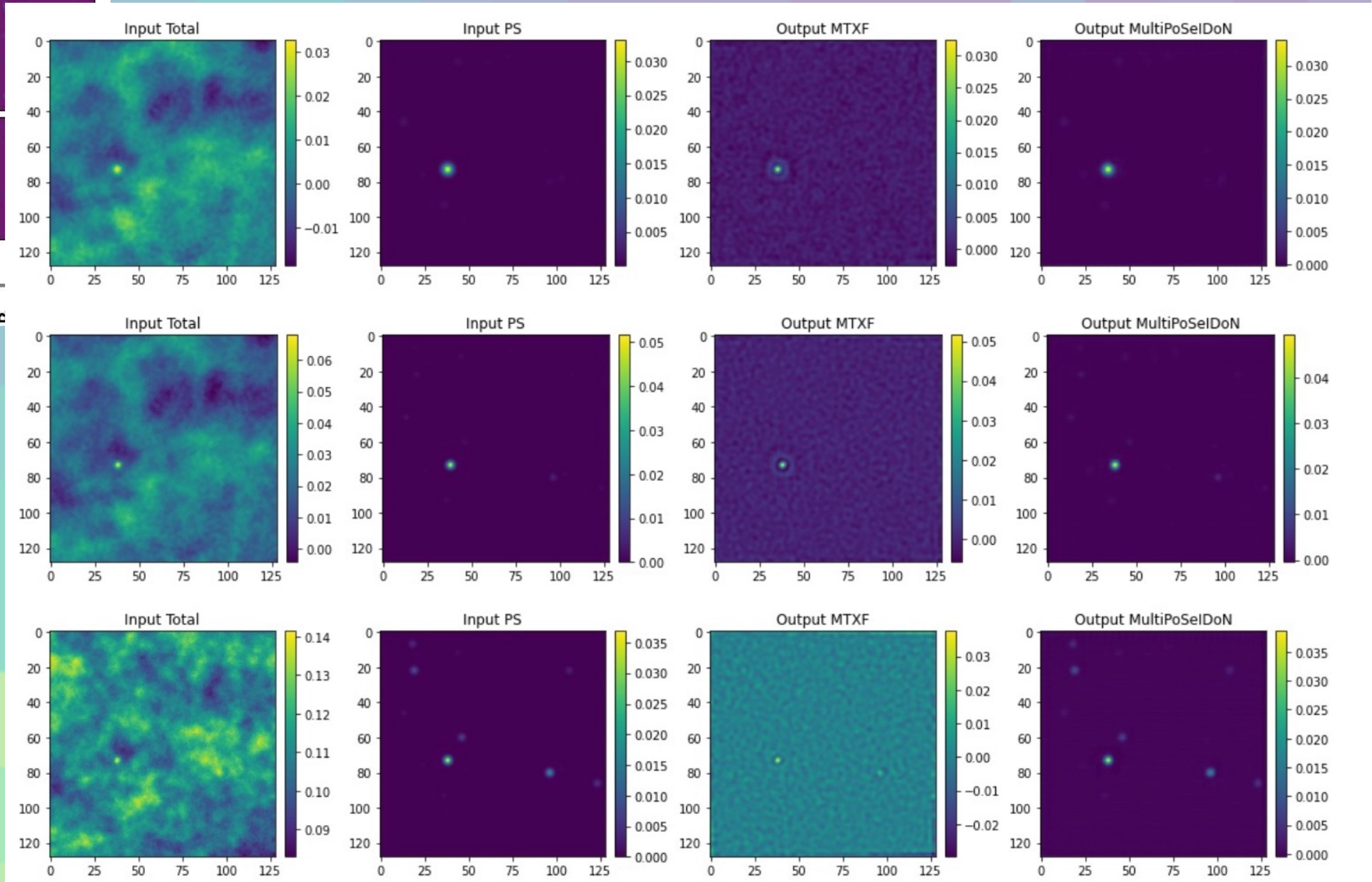
MultiPoSeIDoN – **Multi**frequency PoSeIDoN

Casas+22a



Catalogue: searching peaks (i.e. local maxima)

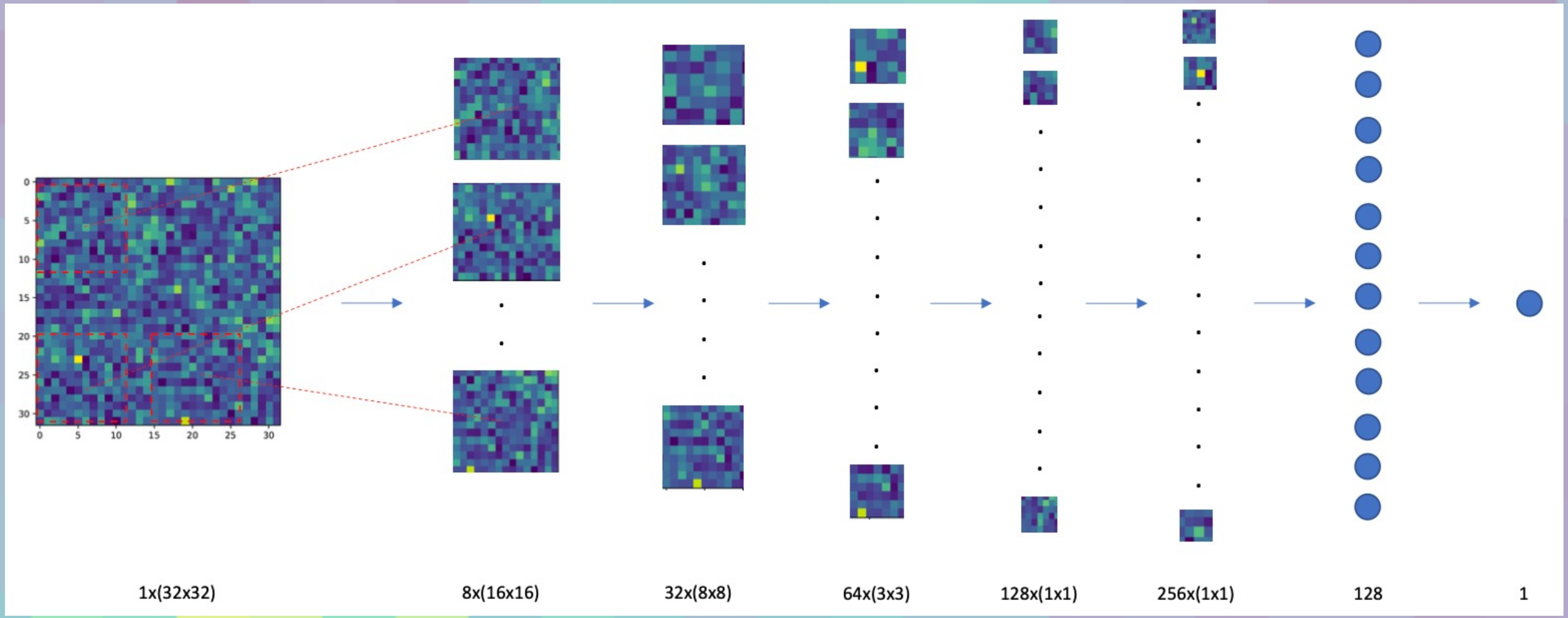
- NN above 60 mJy threshold
- MTXF 4σ



6 conv: 9-18-72-144-288-576 feature maps
6 deconv: 288-144-72-18-9-3 feature maps
500 epochs
Multifrequency simulations
@143, 217 & 353 GHz
128 x 128 pixels (90")
PS flux density scaling w/ freq
50 000 training set (total & PS)
5 000 validation set

POSPEN - **PO**int **S**ource **P**olarization **E**stimation **N**etwork

Casas+23



1^{st} block read the input
Five convolutional blocks of
8-32-64-128-256 filters

+

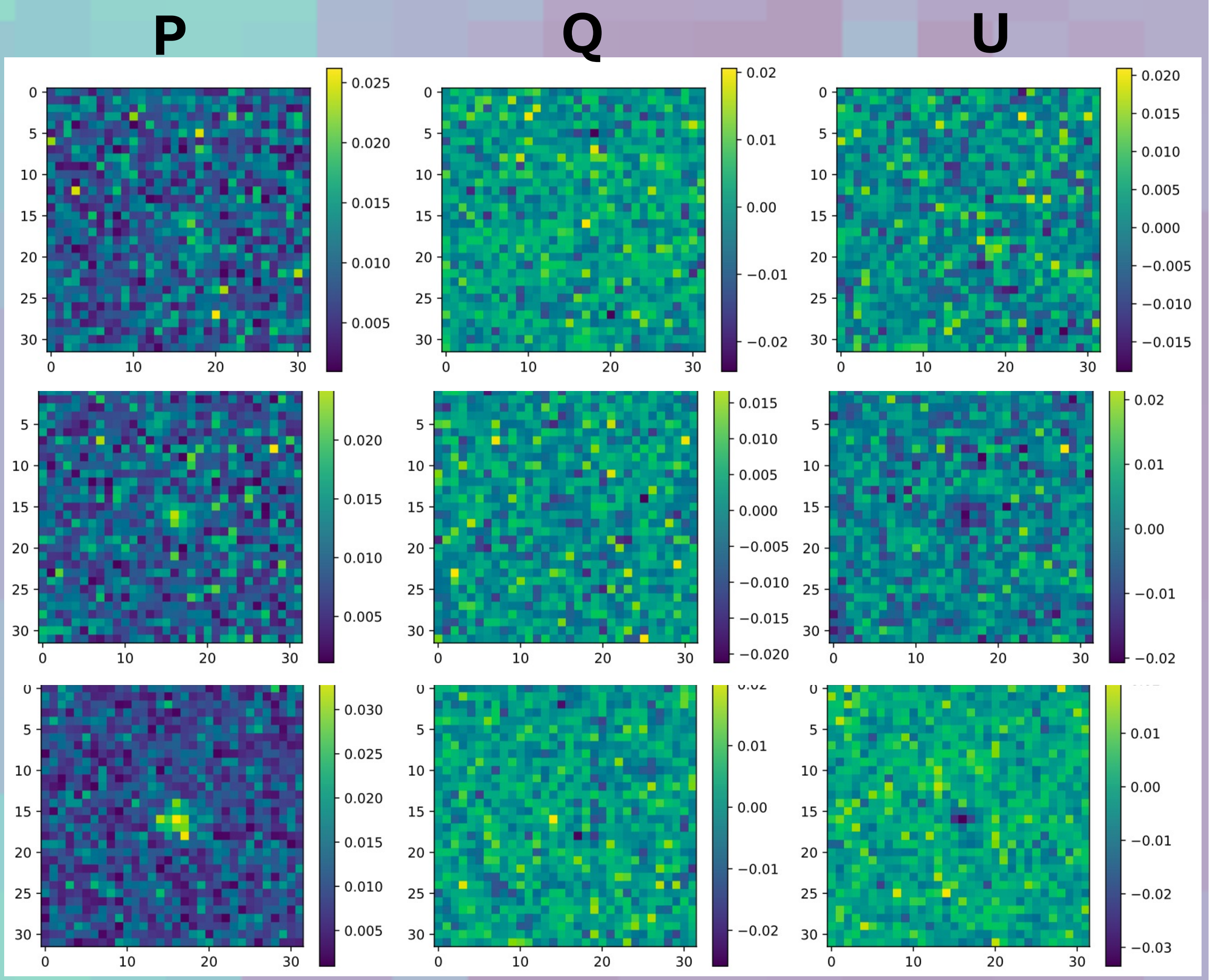
two layers of 128 and 1
neurons converting info to
numerical values

POSPEN - simulations

Simulation in *P*, *Q* and *U*:

- Polarization Planck-like simulations
- @ single frequencies (7 channels)
- a central injected PS (*non-blind method*)
- PS, Radio and IR background following Bonavera+17a,b
- CMB based on the one recovered by SEVEM (PLA)
- Thermal dust and synchrotron based on FFP10 simulations (PLA)
- White noise @ Planck levels
- 32 × 32 pixels of 90”
- Galactic cut at 30 deg

Example of 3 simulations @ 217 GHz in polarization



Bonavera+ TBS

POSPEN - train

Training in *P*, *Q* and *U* separately:

- 15000 sims as training set (label: PS polarization flux density)
- The best model (smallest loss function) is generally obtained at a lower epoch in *P* WRT *Q* and *U*

Validation in *P*, *Q* and *U*:

- 1000 sims as validation set

Epoch @ minimum loss value (training epochs 500)

Freq [GHz]	P min loss epoch	Q min loss epoch	U min loss epoch
30	331	498	473
44	145	493	488
70	224	479	489
100	356	272	446
143	316	281	267
217	95	410	343
353	219	316	352

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POSPEN - validation

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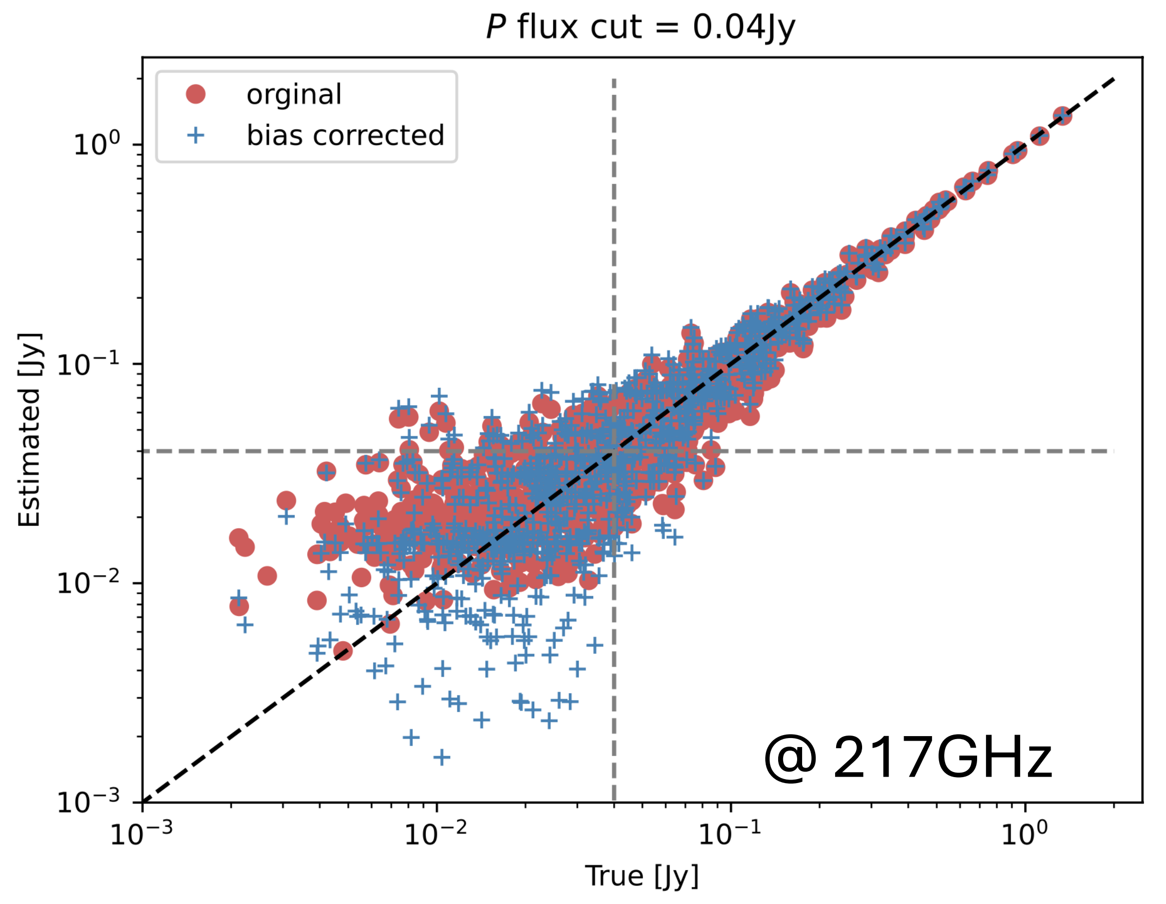
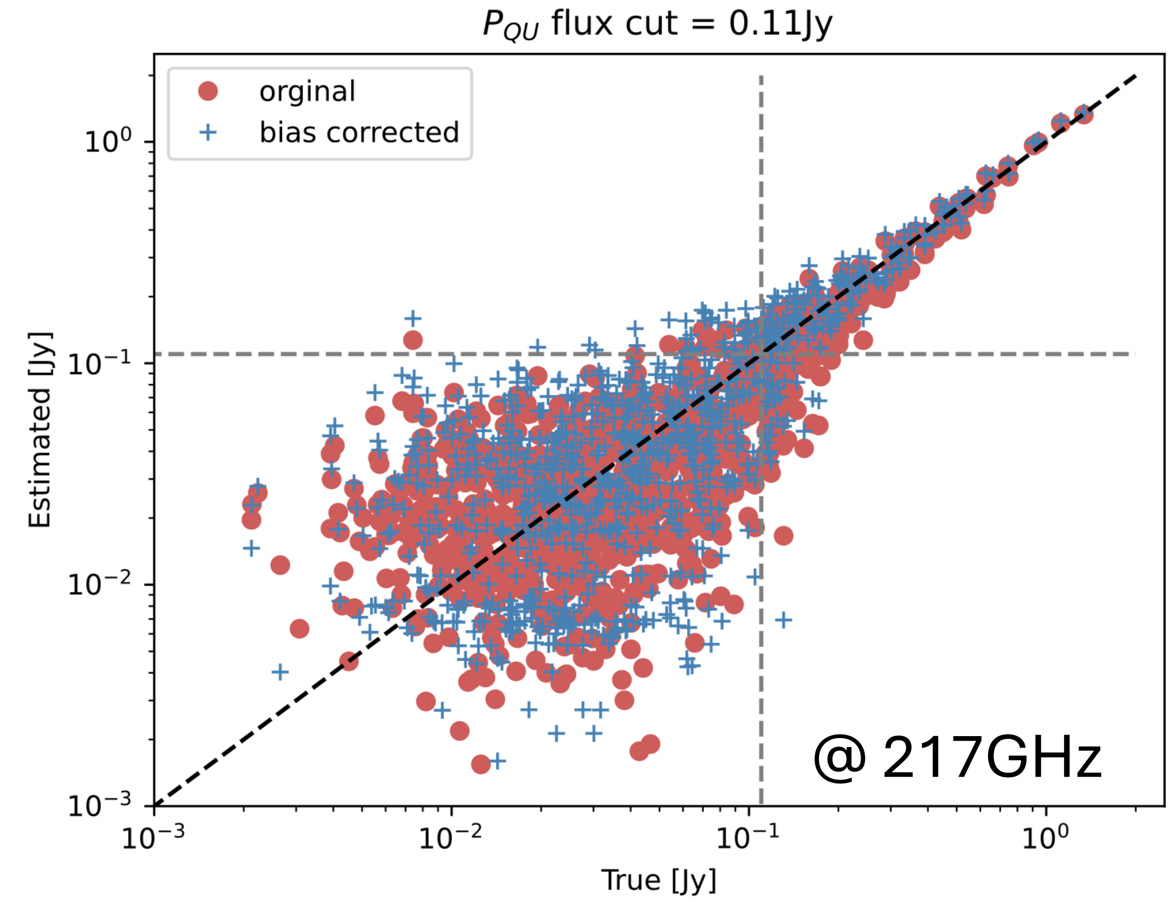
- Unbias by interpolating with the relative error curve
- Trained in *P* (left) and trained in *Q* & *U* and $P_{QU} = \sqrt{Q^2 + U^2}$ (right)
- Done for the 7 Planck channels
- *P* better WRT P_{QU}

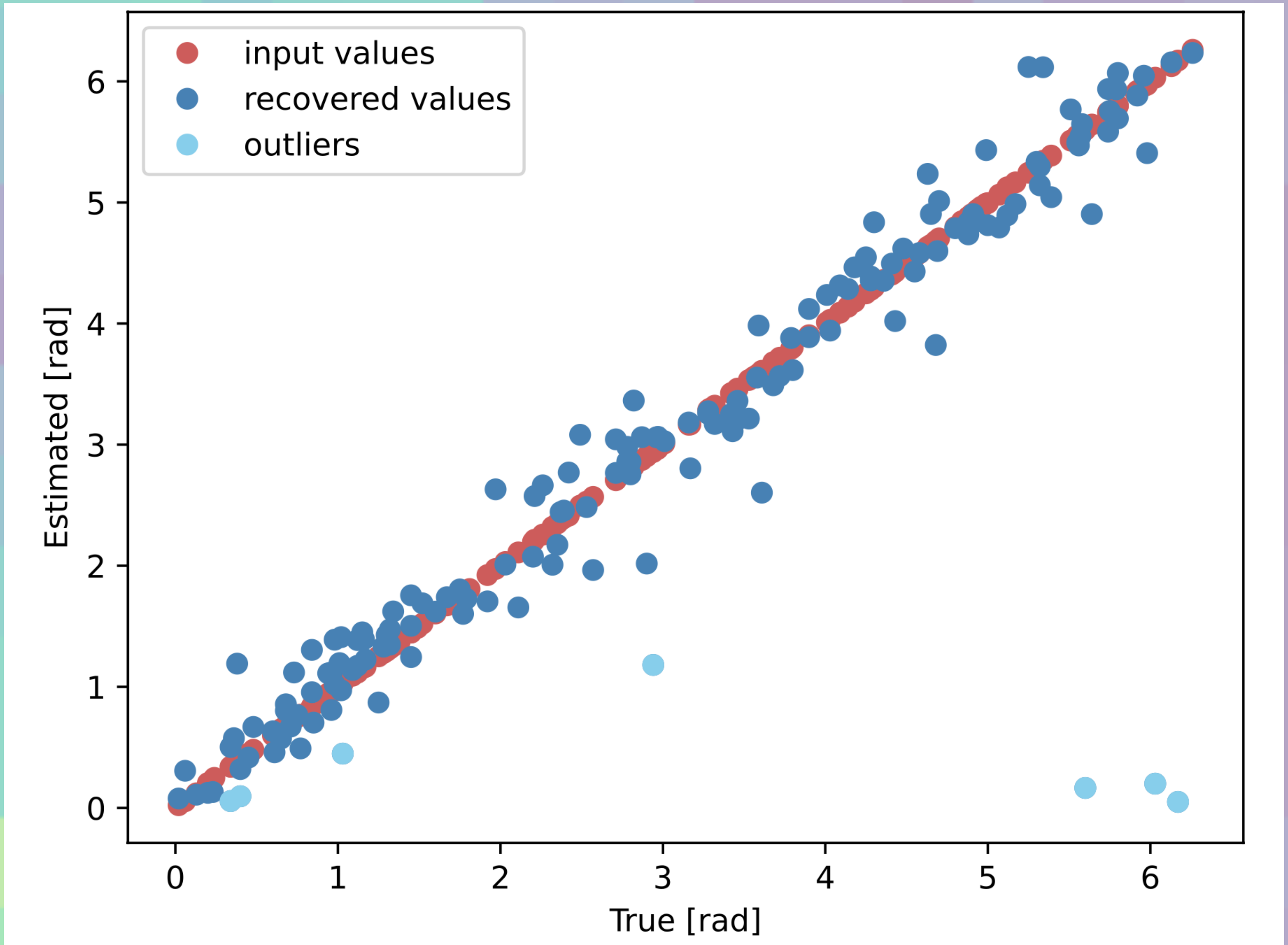




POSPEN - validation

Polarization angles after a flux cut

- No bias issue with *Q* and *U* ratio
- Few outliers
- Dispersion used to compute errors



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POSPEN - validation

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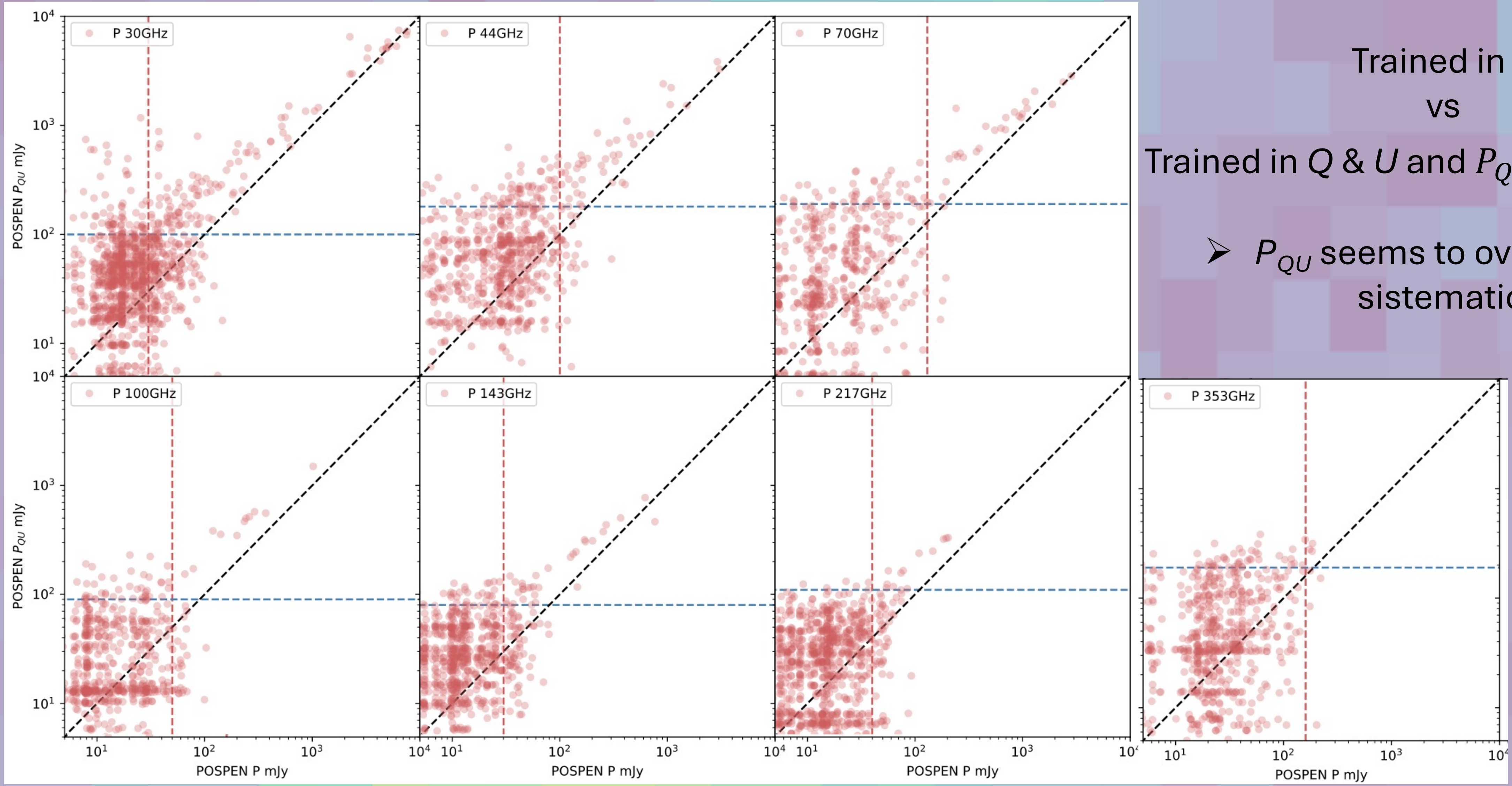


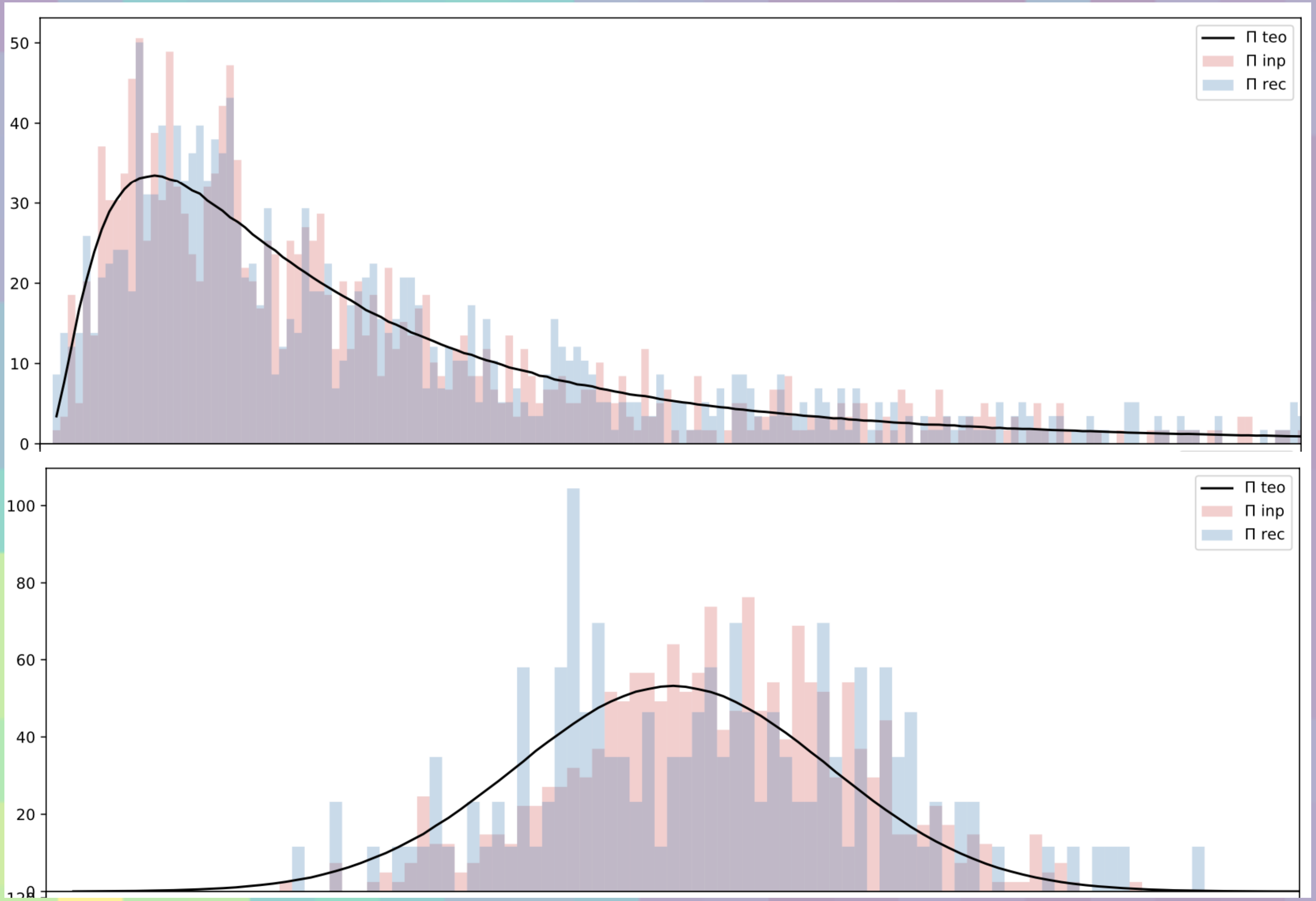
Trained in *P*
vs
Trained in *Q* & *U* and $P_{QU} = \sqrt{Q^2 + U^2}$

- P_{QU} seems to overestimate sistematically

POSPEN - validation

Bonavera+ TBS

POSPEN applied to validation set with injected PS simulated using Π (polarization degree) following a lognormal distribution (top) and a gaussian distro (bottom)

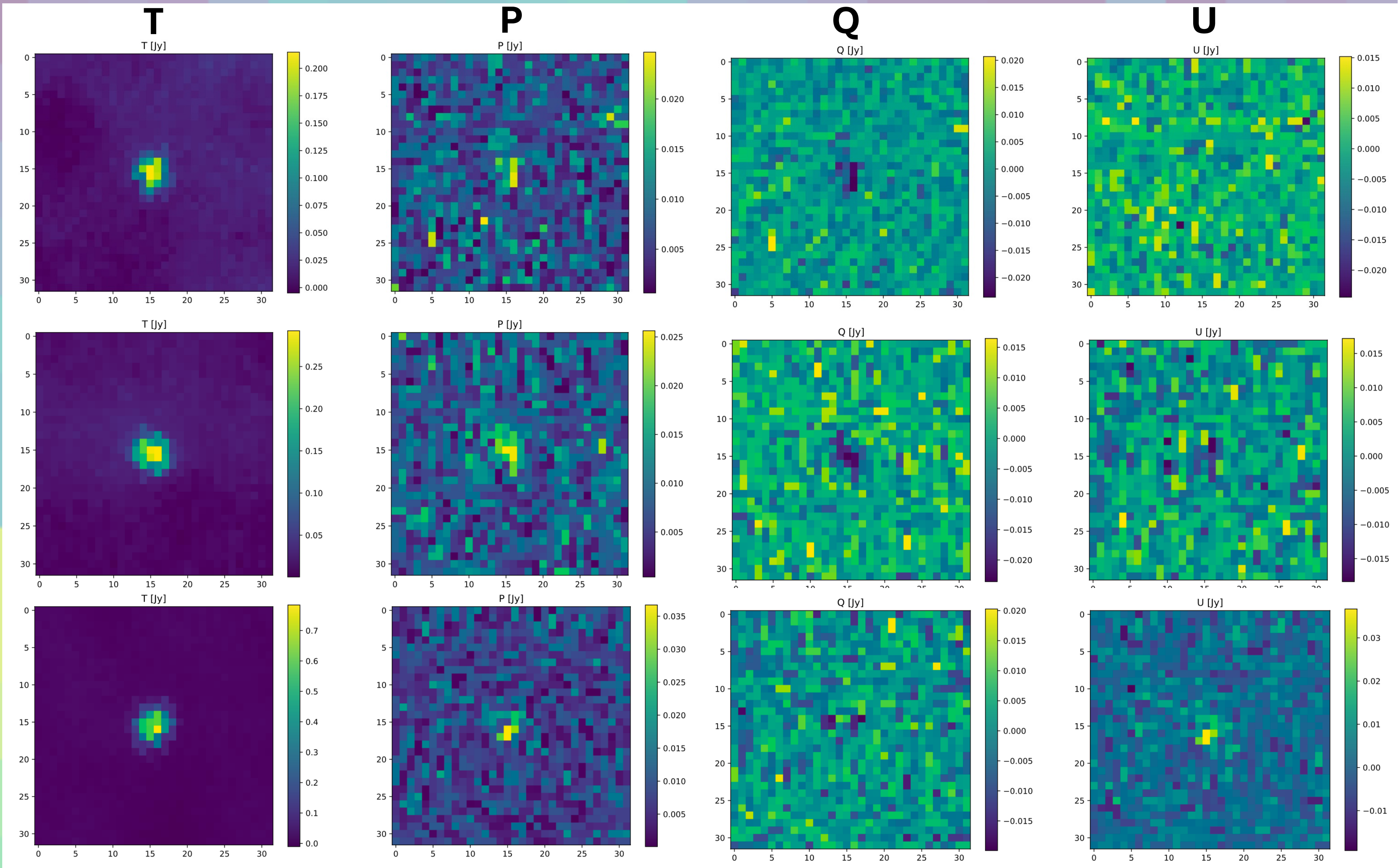


- POSPEN is able to recover the shape of the gaussian distribution, even if trained with a lognormal one

POSPEN - real data

T, *P*, *Q* and *U* patches
of PCCS2 srcs @ 217 GHz

➢ Some very bright pixels (hot pixels?)

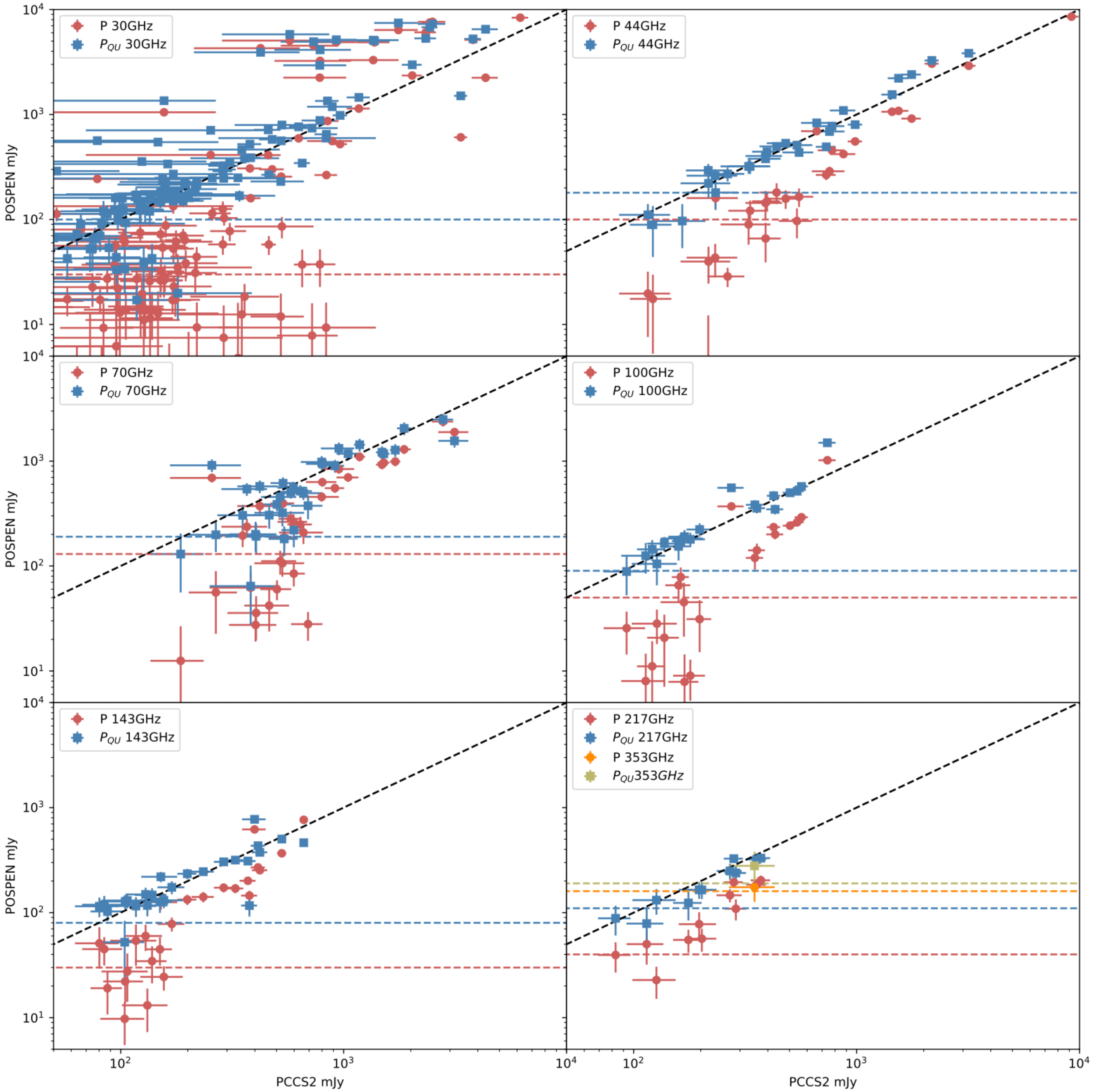


POSPEN - real data

POSPEN @ the PCCS2 positions

- Trained in *P*
- Trained in *Q* & *U* and $P_{QU} = \sqrt{Q^2 + U^2}$

- PCCS2 and P_{QU} in agreement
- Are both overestimating flux densities?



Bonavera+ TBS

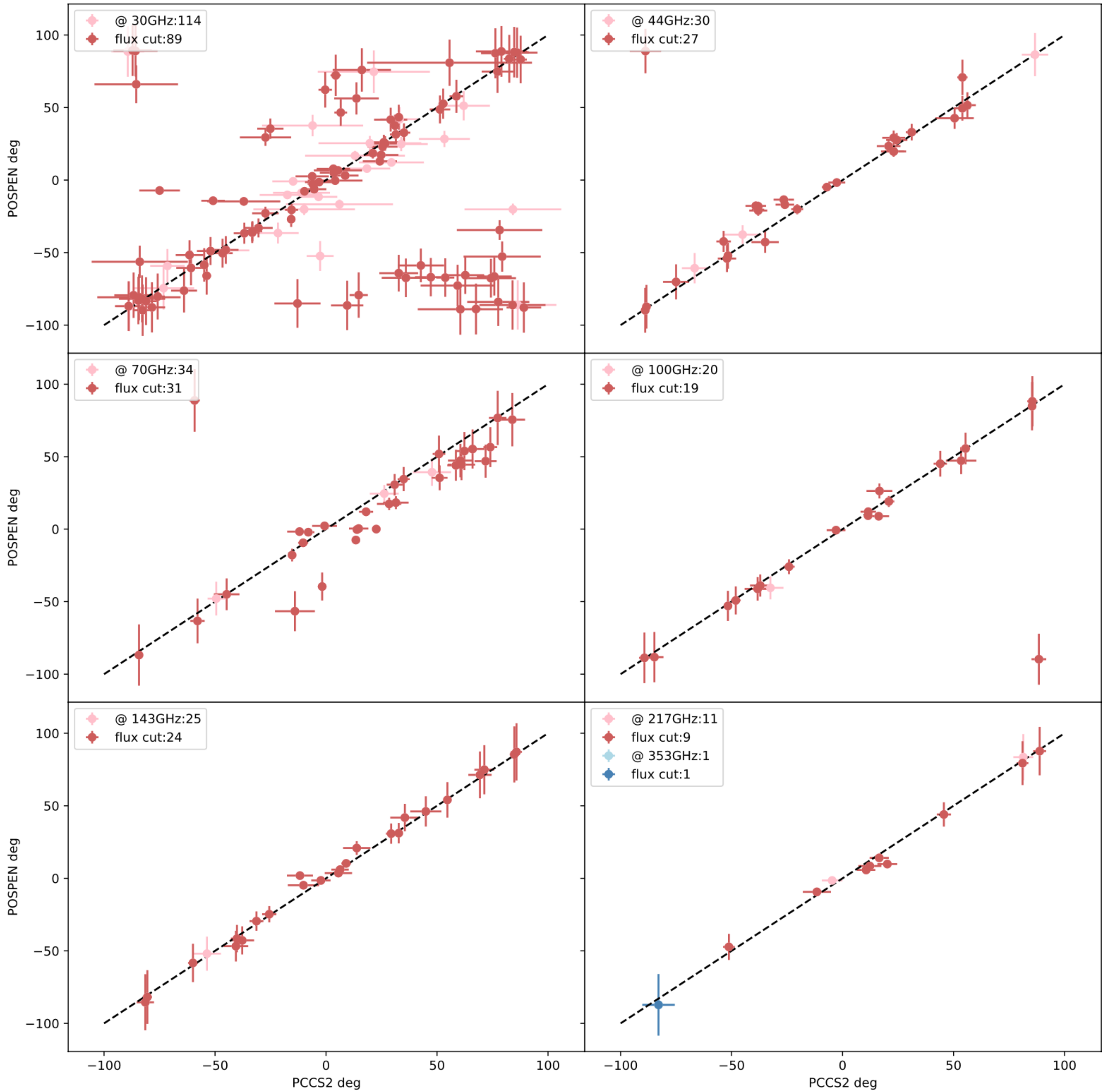
POSPEN - real data

POSPEN @ the PCCS2 positions

polarization angle: $\psi_{QU} = \frac{1}{2}\tan^{-1}(-U/Q)$

- agreement with the PCCS2
- according to validation, there is no bias issue

Bonavera+ TBS



POSPEN - real data

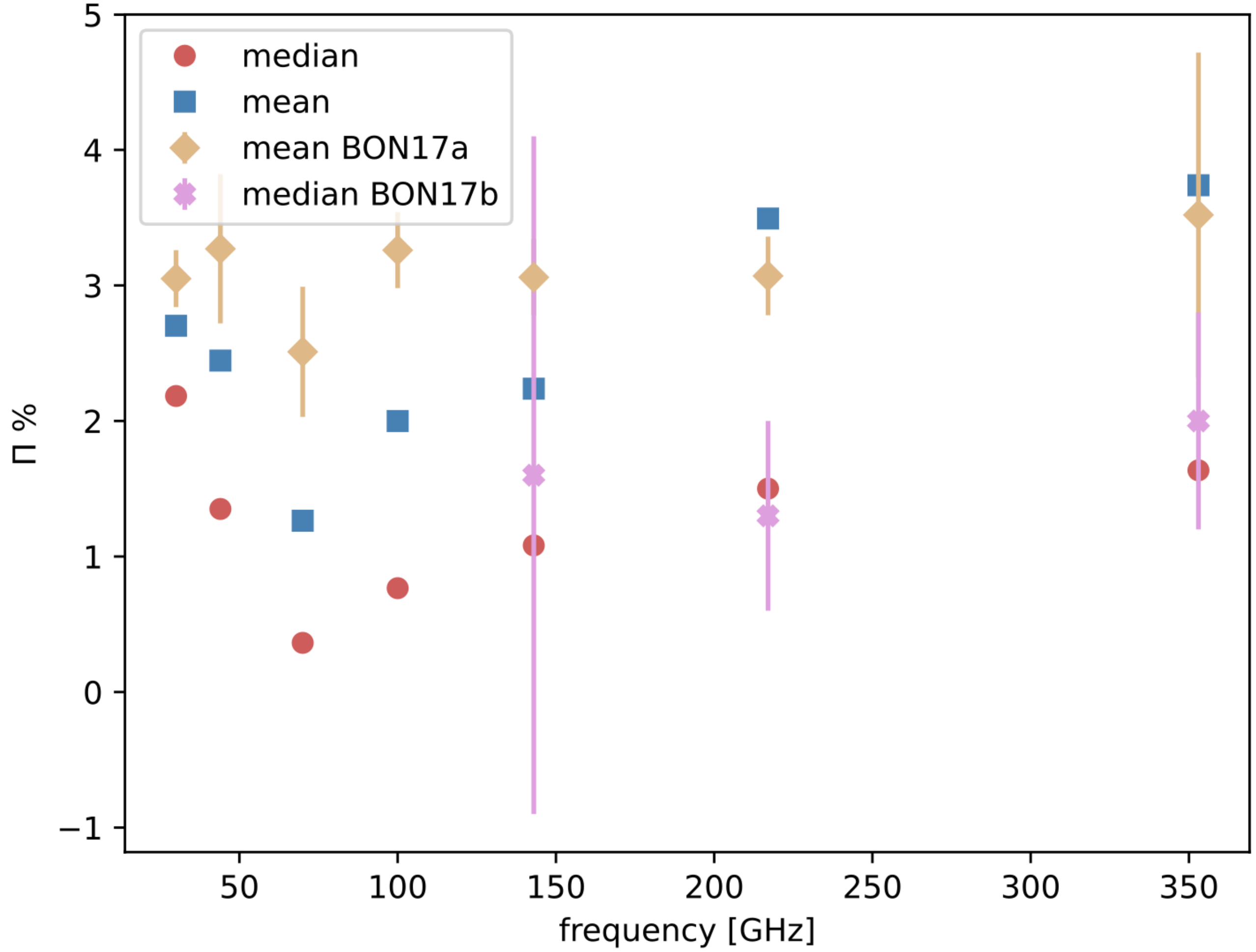
List of total PS in the PCCS2, PS w/ polarization estimations in PCCS2, PCCS2 PS confirmed w/ POSPEN, POSPEN new PS, PSPEN total estimated PS in the 7 channels

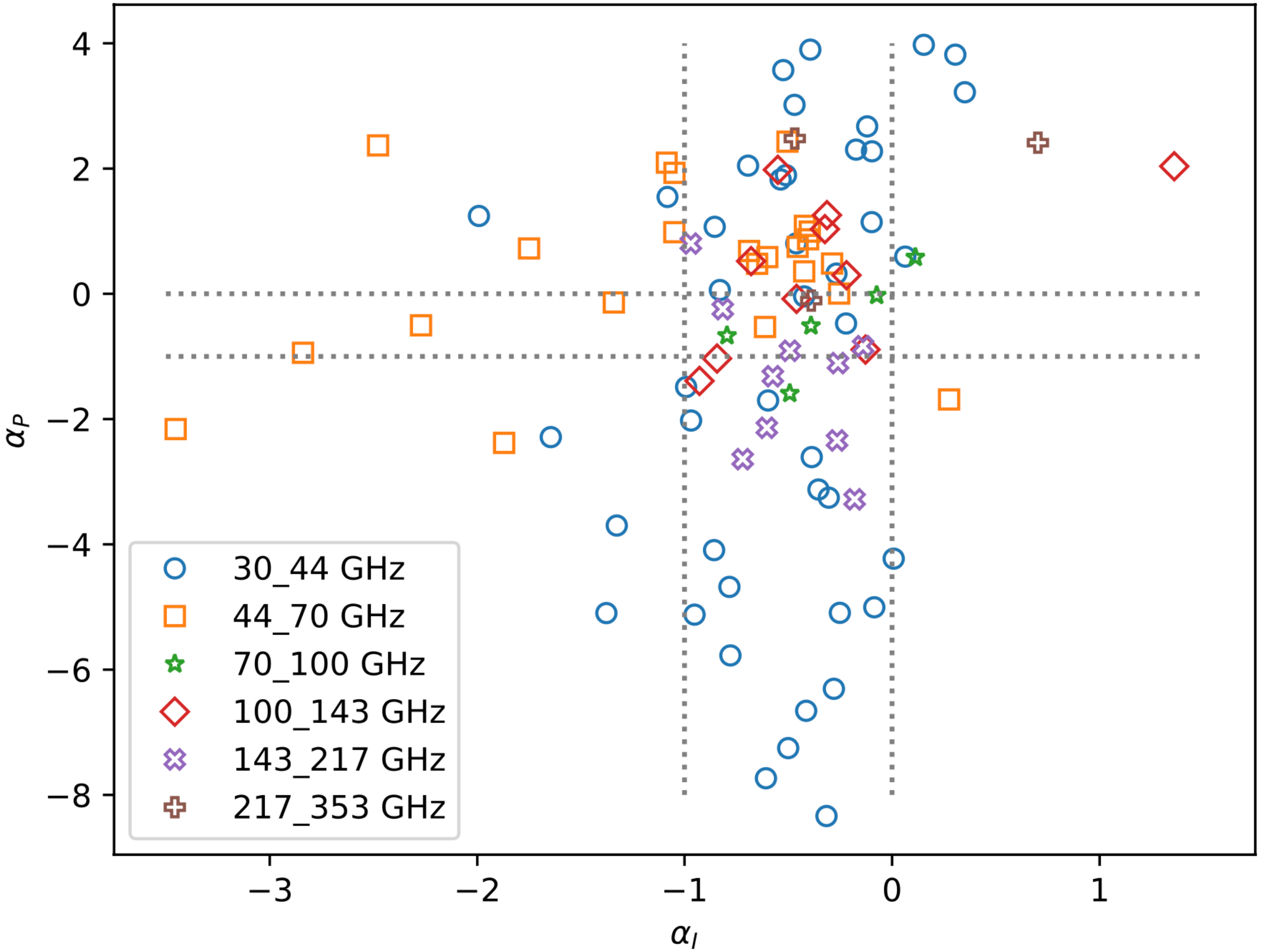
- Considering all channels, increase in the polarization estimantions of approx a factor 3

Freq [GHz]	PCCS2 I	PCCS2 P	confirmed by POSPEN	POSPEN new	POSPEN tot
30	1560	114	61	302	363
44	934	30	20	52	72
70	1296	34	23	8	31
100	1742	20	11	35	46
143	2160	25	19	93	112
217	2135	11	9	64	73
353	1344	1	1	8	9

POSPEN - real data

Bonavera+ TBS





POSPEN applied to the PS in the PCCS2:

- ➢ Polarization fraction @ 7 channels
  - agreement w/ usual values at lower freqs
  - Estimation at highest freqs!
- ➢ NO correlation *T* vs *P* spectral indices

Conclusions

NN with simulations:

- Lower flux densities limit: larger number of detected PS
- Smaller number of spurious detections
- Not a “filter” (no Fourier space), then no ringing or border effects
- Multi-frequency methodology in *T*, very important for spectral characterization of galaxies
- Estimation of polarization angle for even not so bright PS
- Recovery of the correct Π distribution

POSPEN for Planck:

- Not stightforward application
- Discrepancies bw P_{NN} & $P_{planck}(P_{QU})$?
- (hot pixels issue?)
- Hundreds of new sources in *P*
- NO correlation *T* vs *P* spectral indices
- Polarization angle in agreement with PCCS2
- Π in agreement with previous results