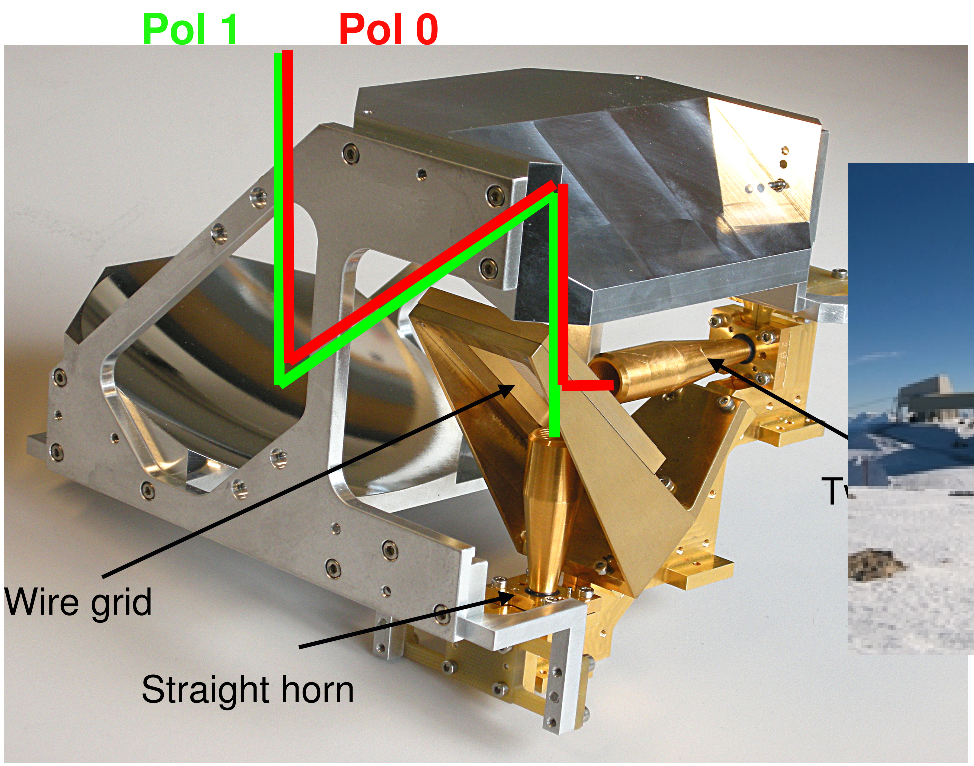
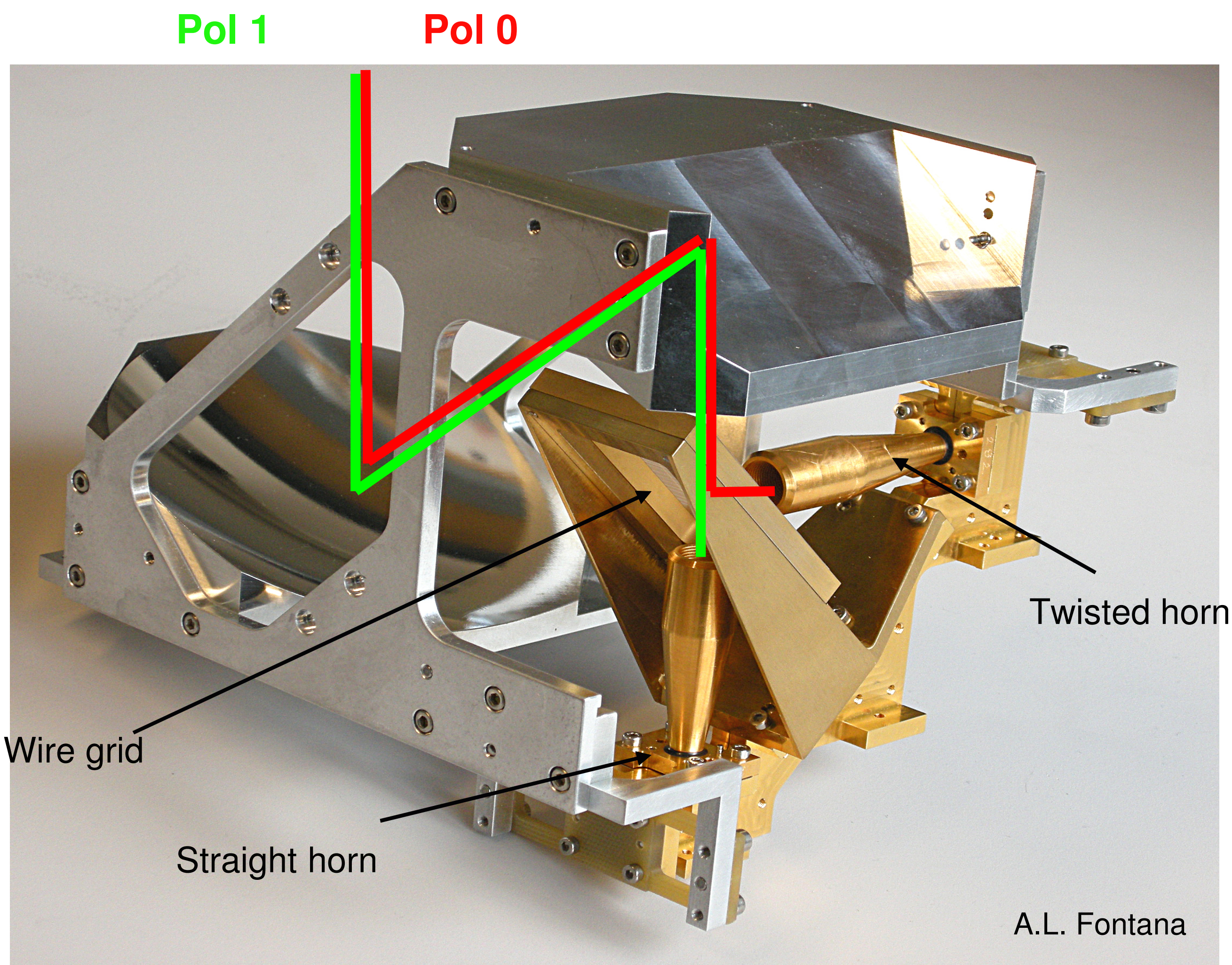
The PdBI and Polarization



Sascha Trippe

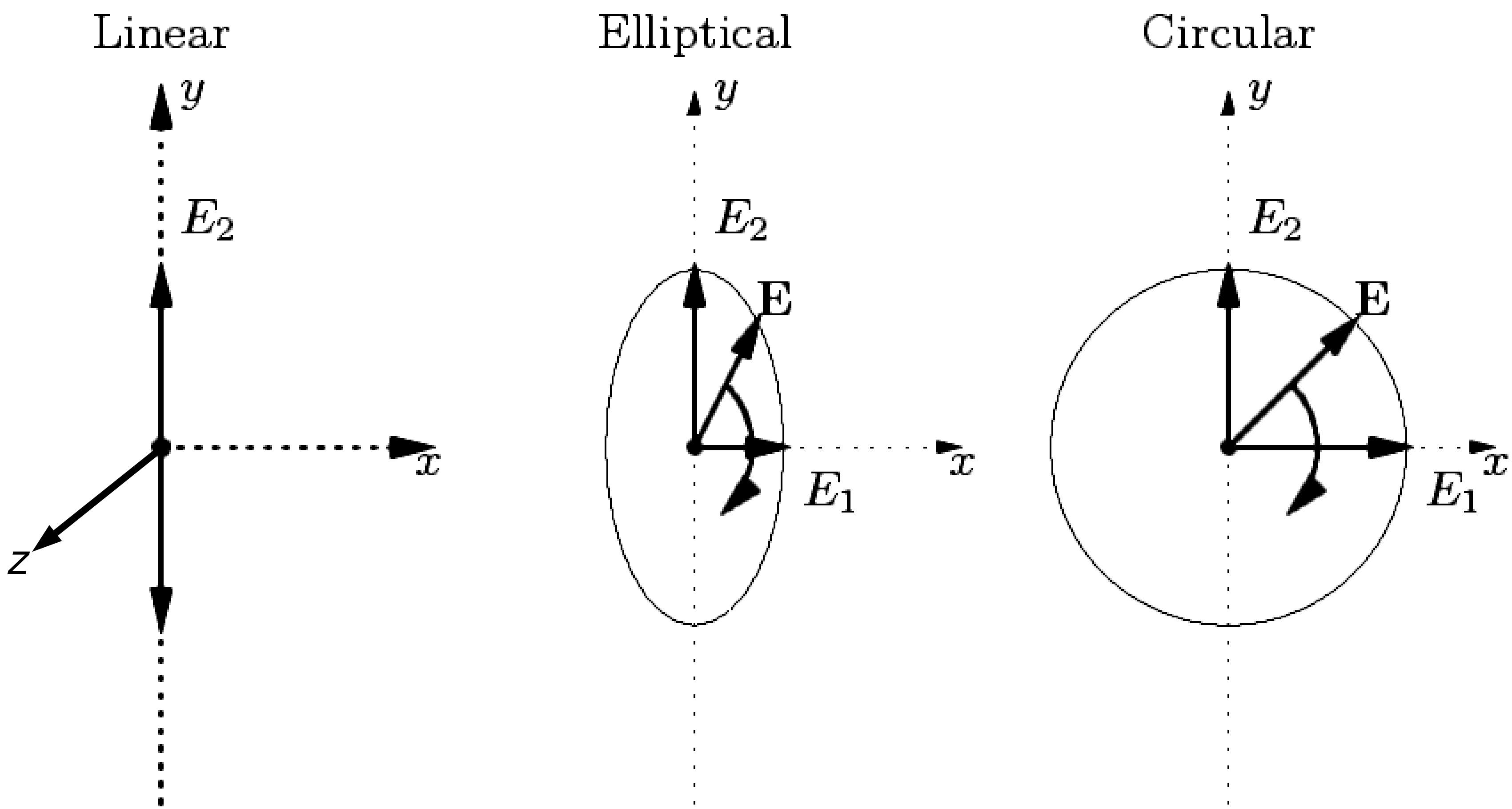
IRAM Grenoble

The PdBI uses dual polarization receivers



Two orthogonal linear polarizations: horizontal + vertical w.r.t. the antenna frame

Polarization basics



Wave propagates in *z* direction

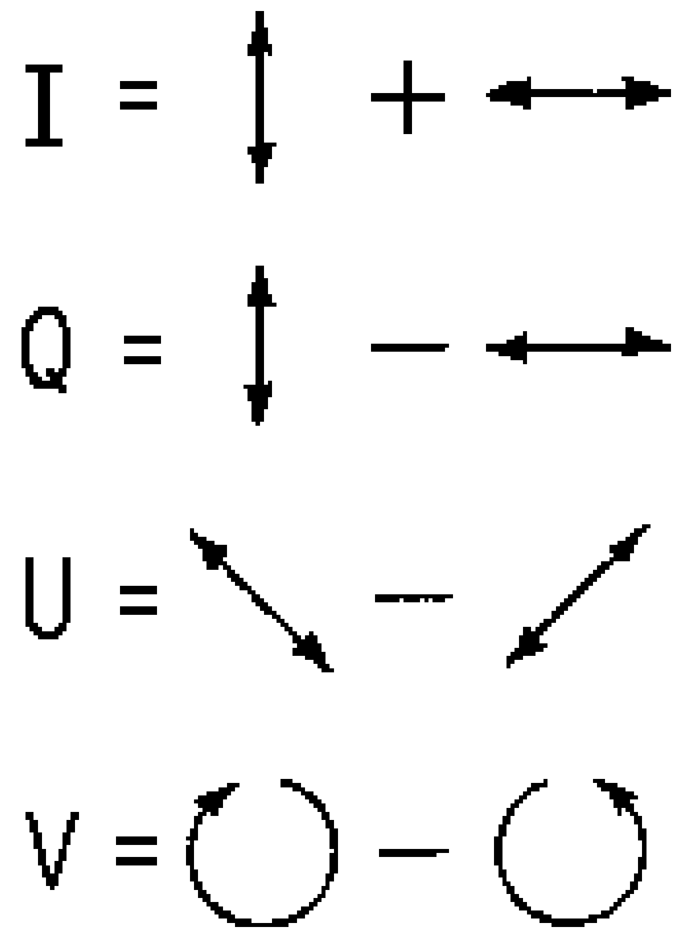
4 Stokes parameters for a full description

$$I = \langle E_x^2 \rangle + \langle E_y^2 \rangle,$$

$$Q = \langle E_x^2 \rangle - \langle E_y^2 \rangle,$$

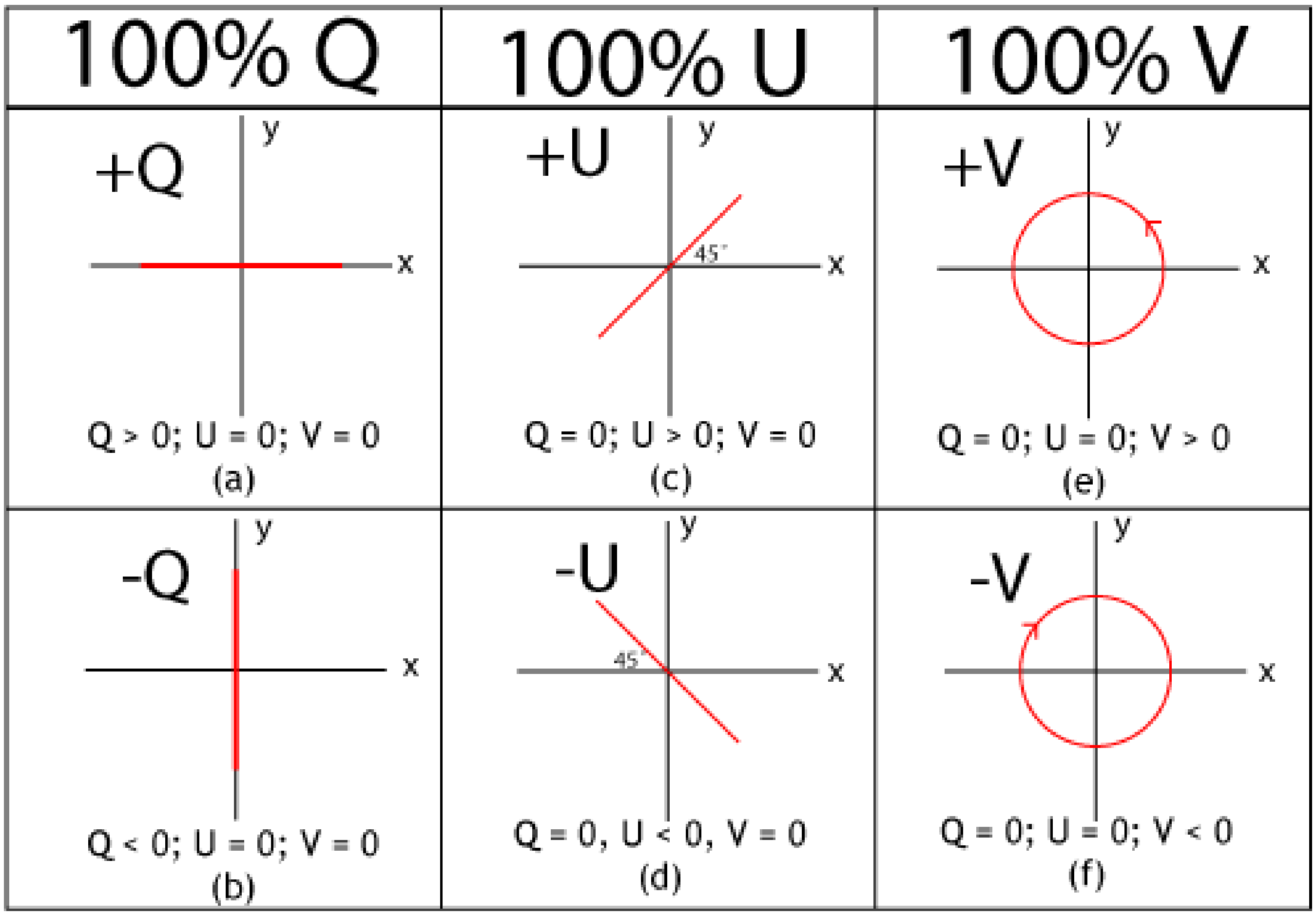
$$U = 2\langle E_x E_y \cos\delta \rangle,$$

$$V = 2\langle E_x E_y \sin\delta \rangle.$$



δ is the phase difference between E_x and E_y

Three extreme examples



Note: Q ↔ U via rotation of the coordinate system

Total intensity

$$I = \langle E_x^2 \rangle + \langle E_y^2 \rangle,$$

$$Q = \langle E_x^2 \rangle - \langle E_y^2 \rangle,$$

$$U = 2\langle E_x E_y \cos \delta \rangle,$$

$$V = 2\langle E_x E_y \sin \delta \rangle.$$

Linear polarization

$$I = \langle E_x^2 \rangle + \langle E_y^2 \rangle,$$

$$Q = \langle E_x^2 \rangle - \langle E_y^2 \rangle,$$

$$U = 2\langle E_x E_y \cos\delta \rangle,$$

$$V = 2\langle E_x E_y \sin\delta \rangle.$$

$$m_L = \frac{\sqrt{Q^2 + U^2}}{I}$$

$$\chi = \frac{1}{2}\arctan\frac{U}{Q}$$

Circular polarization

$$I = \langle E_x^2 \rangle + \langle E_y^2 \rangle,$$

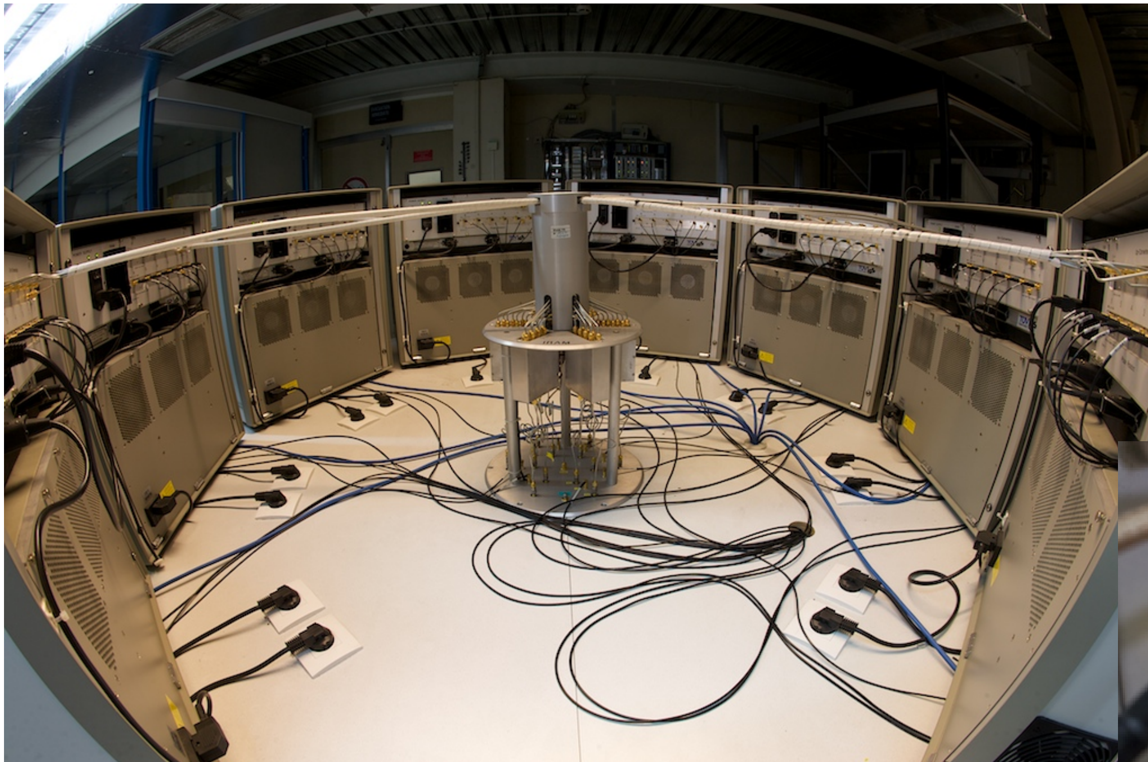
$$Q = \langle E_x^2 \rangle - \langle E_y^2 \rangle,$$

$$U = 2\langle E_x E_y \cos\delta \rangle,$$

$$V = 2\langle E_x E_y \sin\delta \rangle.$$

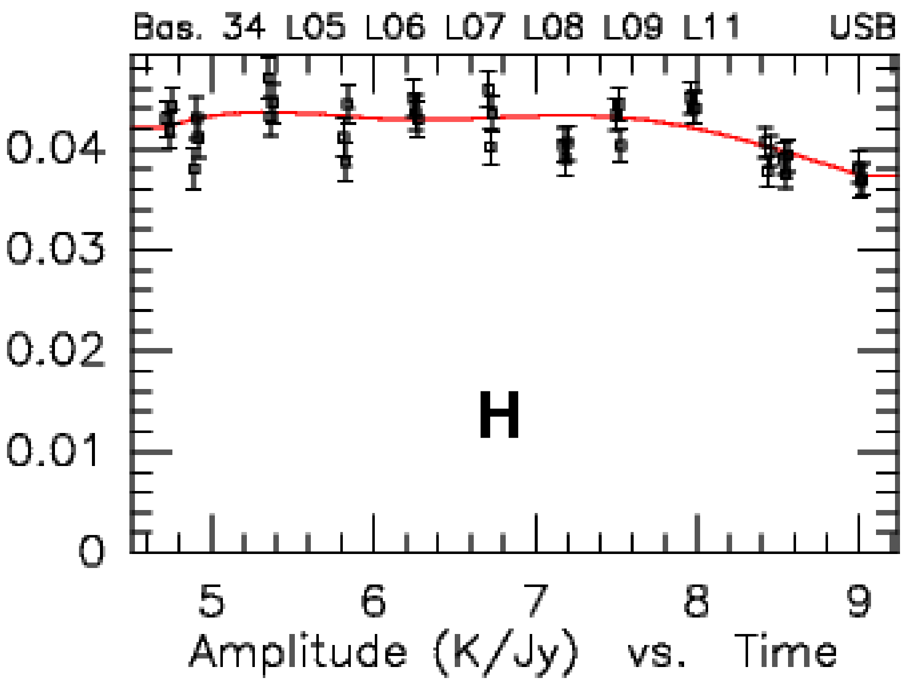
$$m_C = \frac{V}{I}$$

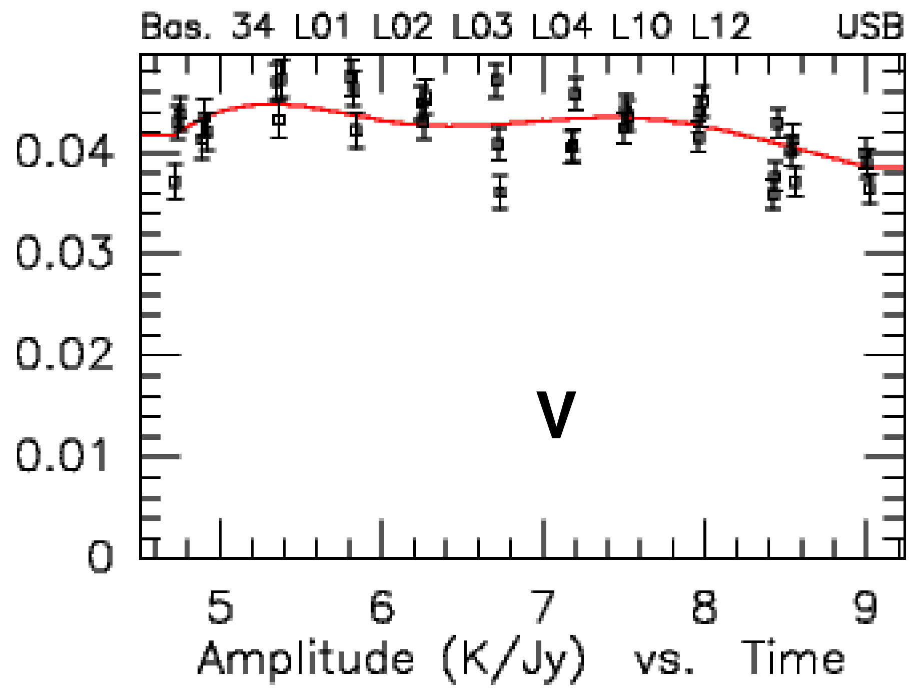
Polarimetry is limited by the correlator wiring



For each baseline only HH and VV are correlated ➔ only Stokes *I*, *Q*, *U* are accessible

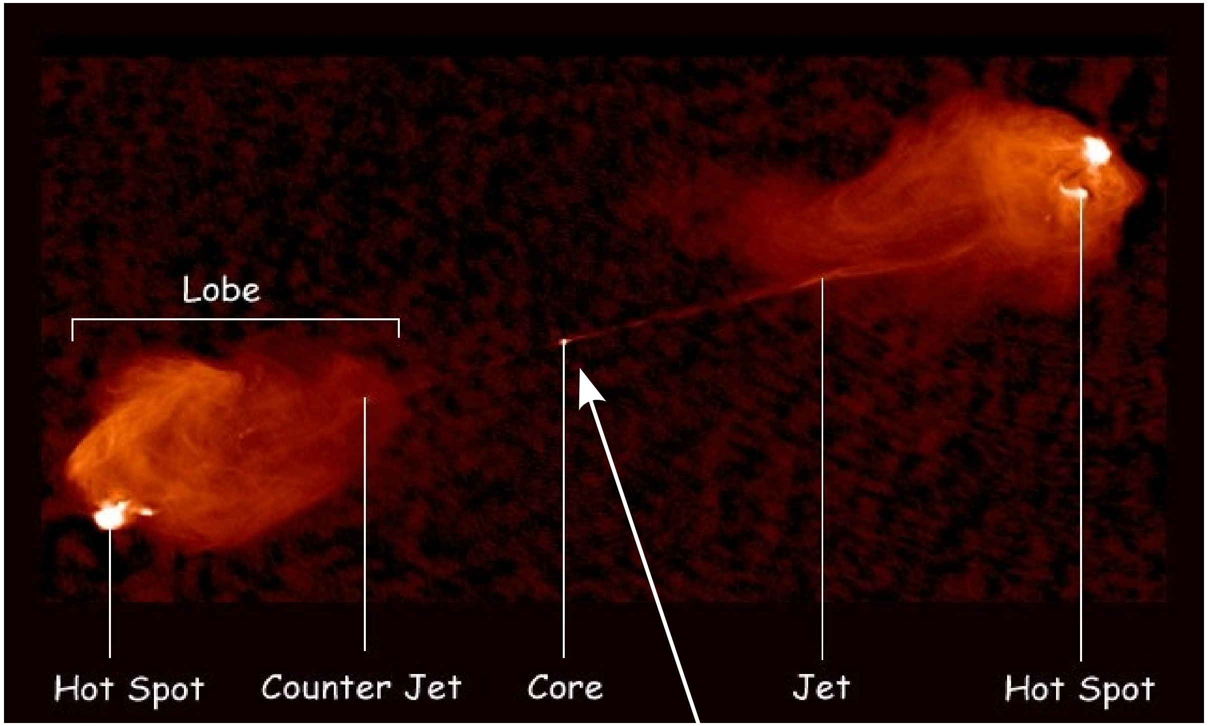
Observations are sensitive to polarization





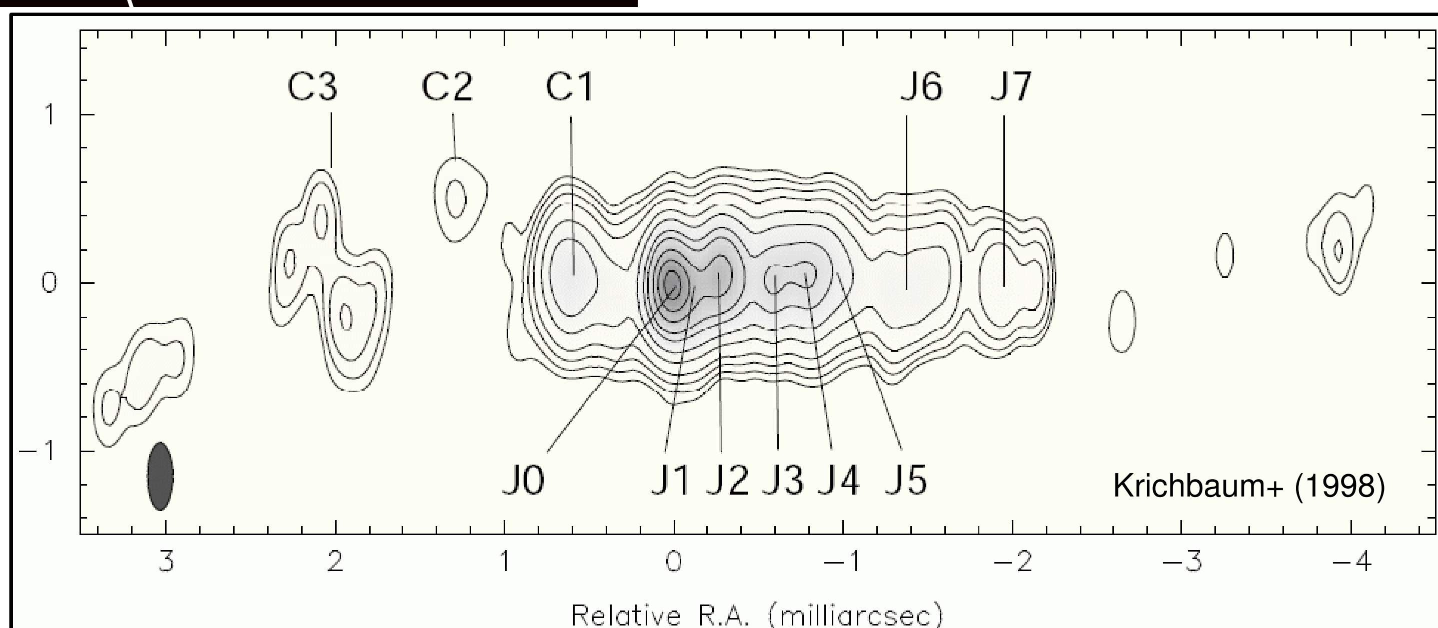
➔ Linear polarization of calibration quasars becomes important

Quasars are complex sources

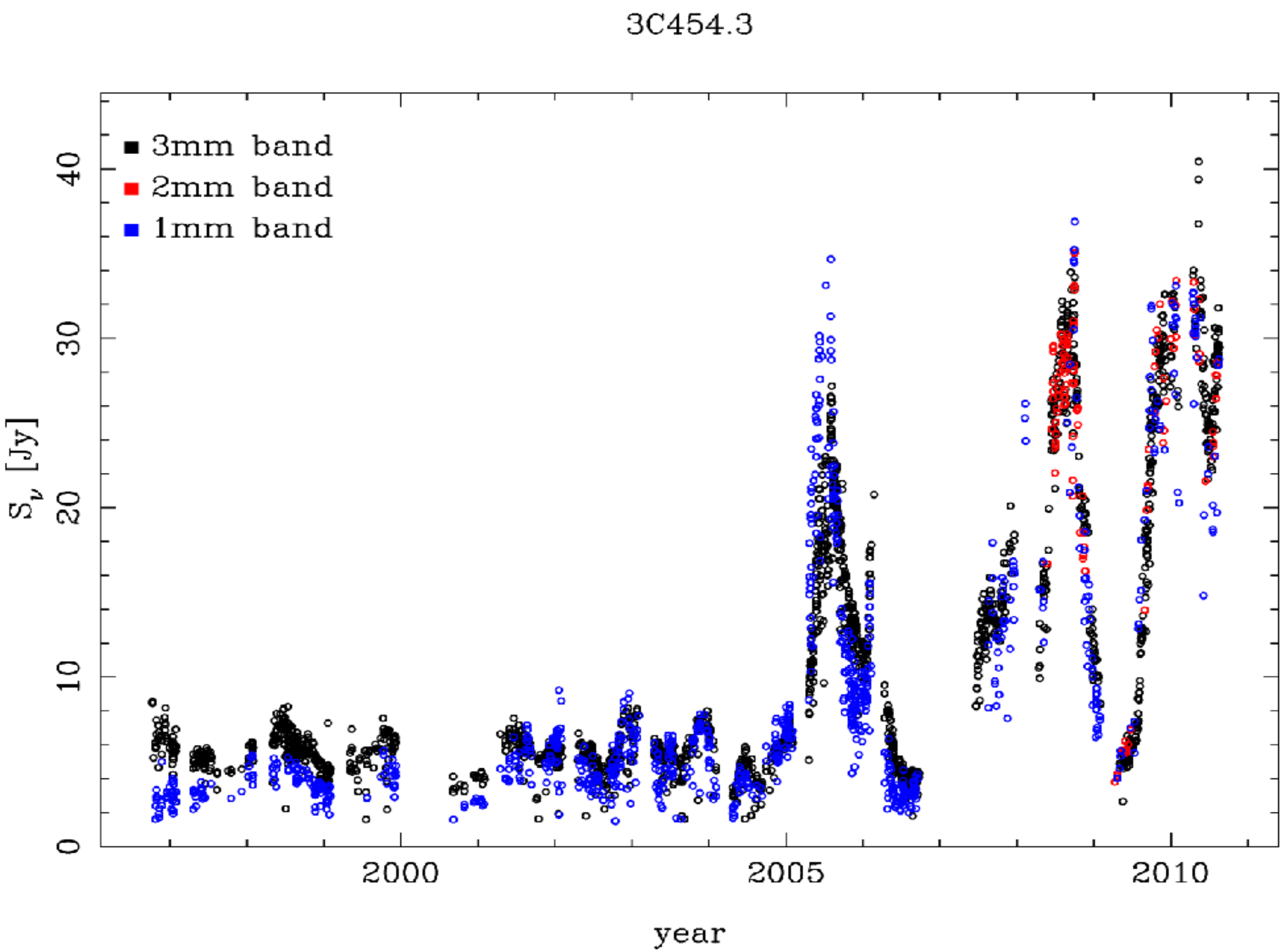


U Oulu

Cygnus A



Quasars are very active sources



Good for calibration? **Yes** – on timescales of hours

Quasars could be highly polarized

Sources with powerlaw spectra $S_\nu \propto \nu^{-\alpha}$ with α ~ 0 ... +1

have electron energy powerlaw spectra with indices $\Gamma = 2\alpha + 1$

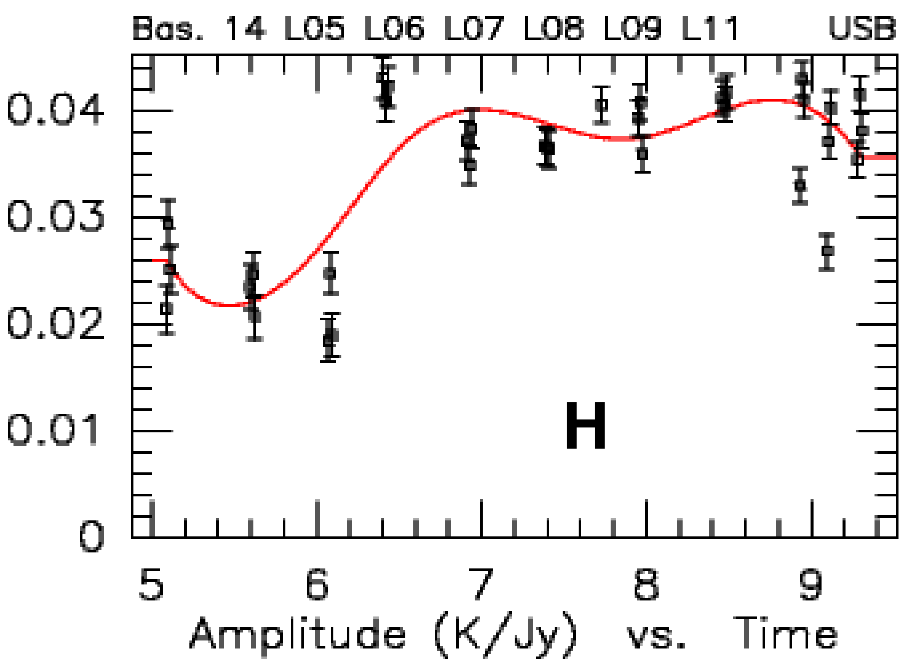
resulting in a degree of linear polarization
(for optically thin, homogeneous sources)

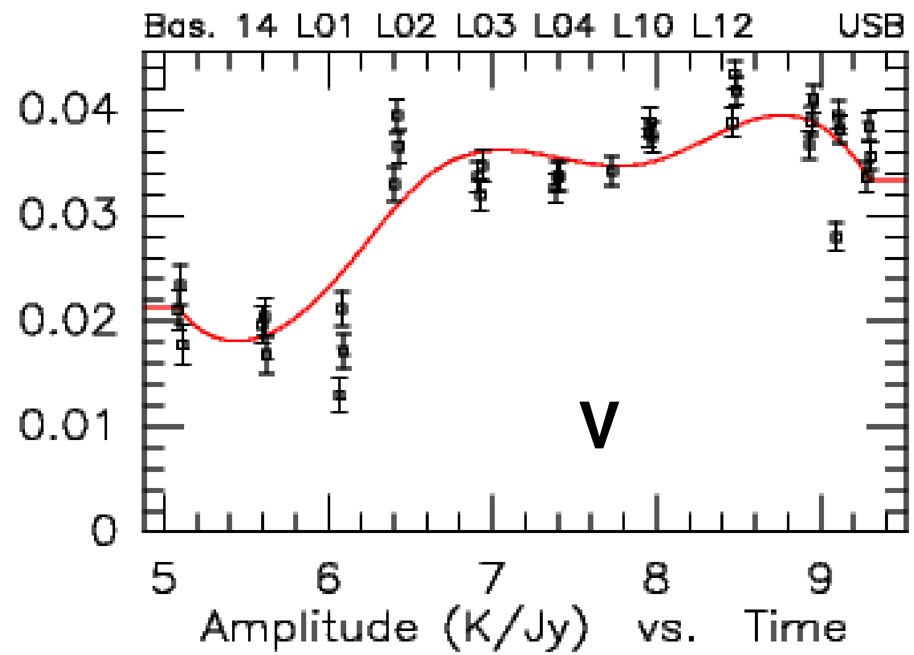
$$m_L = \frac{\Gamma + 1}{\Gamma + 7/3}$$

➔ Polarizations of ~60% can be expected

➔ Polarization monitoring is necessary

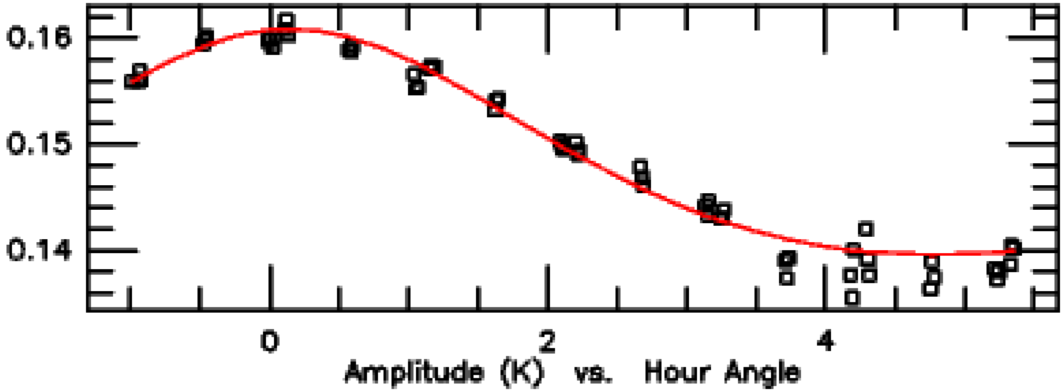
We must quantify the impact of polarization



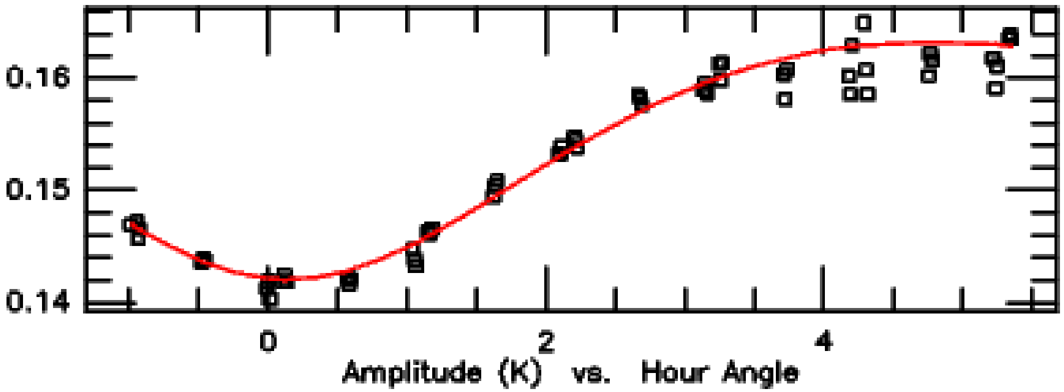


Non-recognized calibrator polarization can add systematic errors to the data

Each PdBI observation collects polarization information on calibration quasars

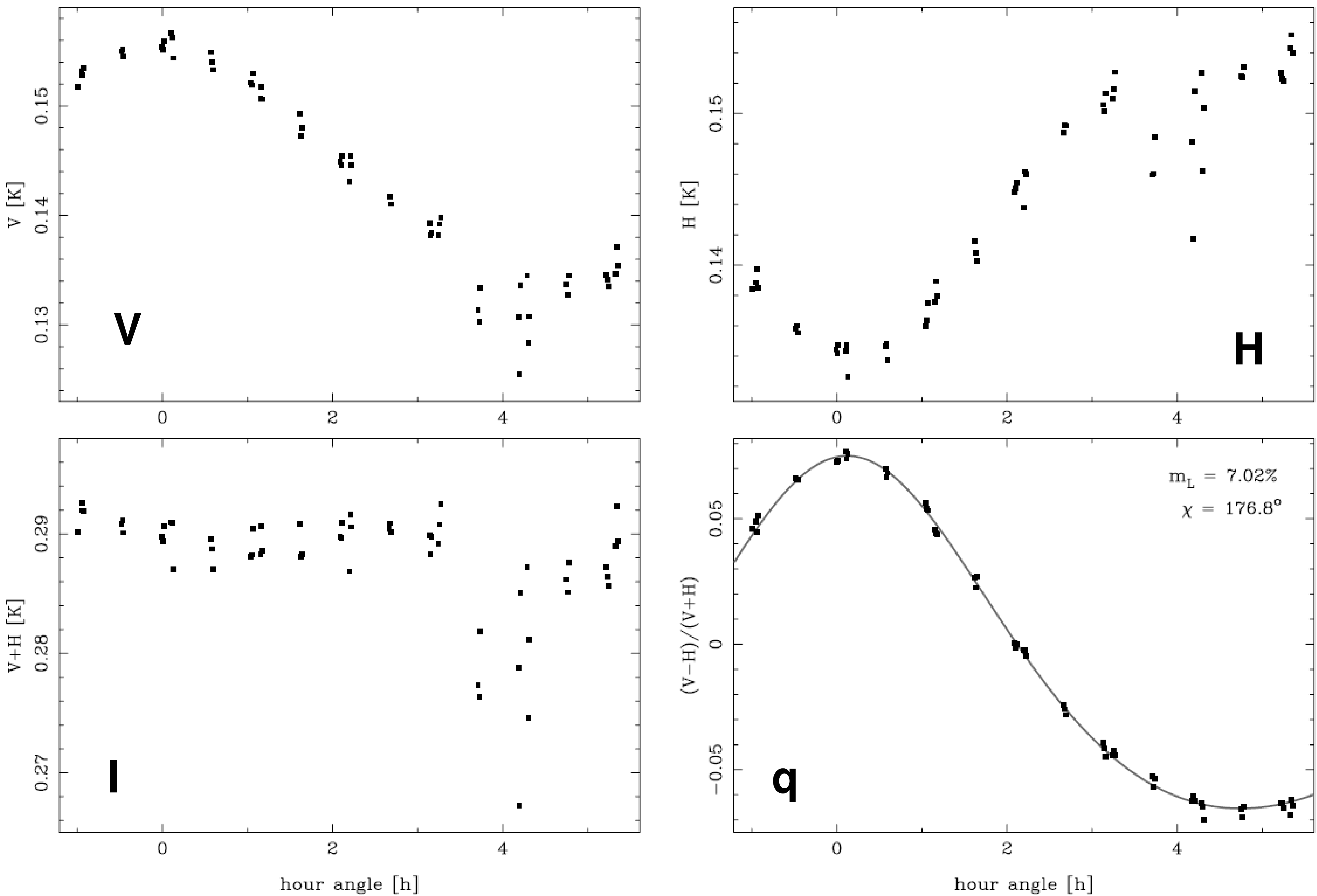


Vertical (w.r.t. antenna)



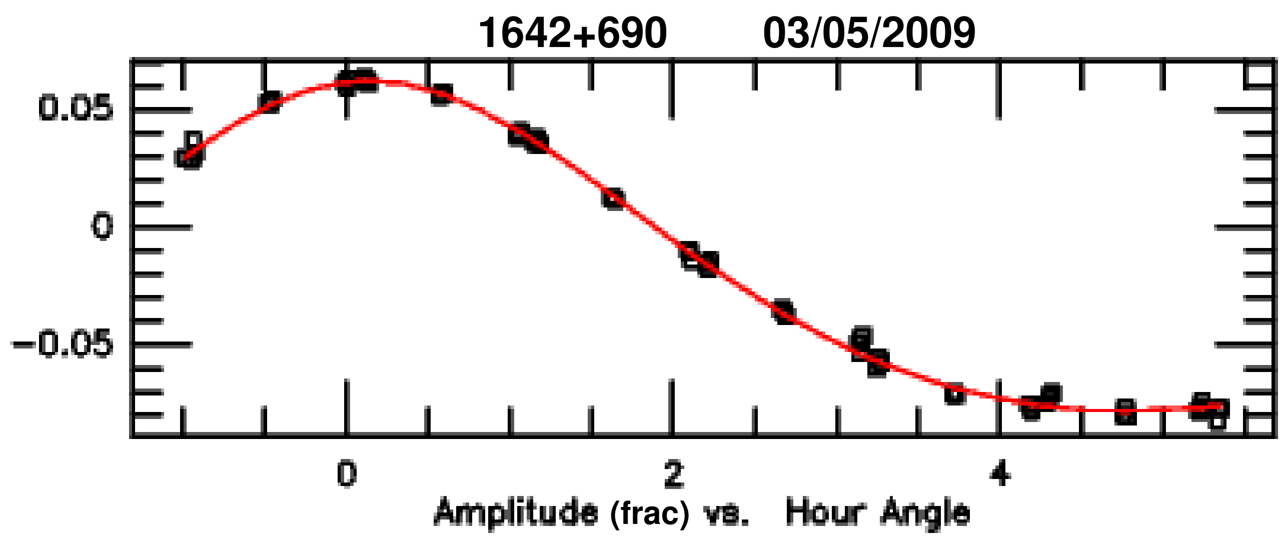
Horizontal (w.r.t. antenna)

Exploiting the properties of polarization



Earth rotation polarimetry ➔ linear polarization

$$q(h) = \frac{V-H}{V+H}(h) =$$



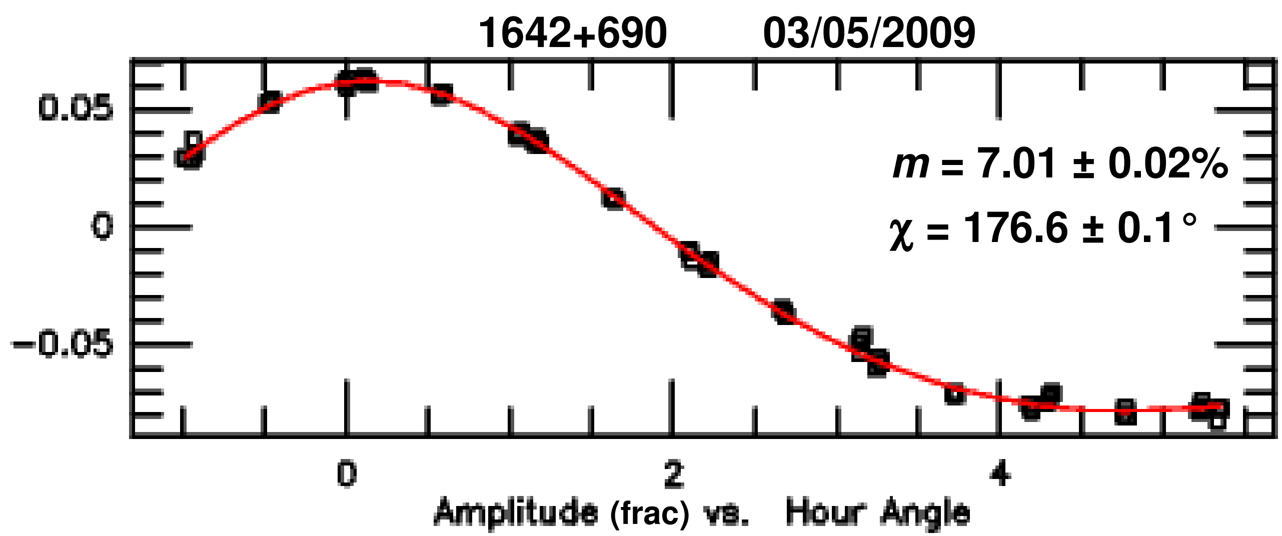
$$q(\psi) = \frac{Q}{I}\cos(2\psi) + \frac{U}{I}\sin(2\psi)$$

h: hour angle

ψ: parallactic angle

Earth rotation polarimetry ➔ linear polarization

$$q(h) = \frac{V-H}{V+H}(h) =$$



$$q(\psi) \equiv m \cos[2(\psi-\chi)]$$

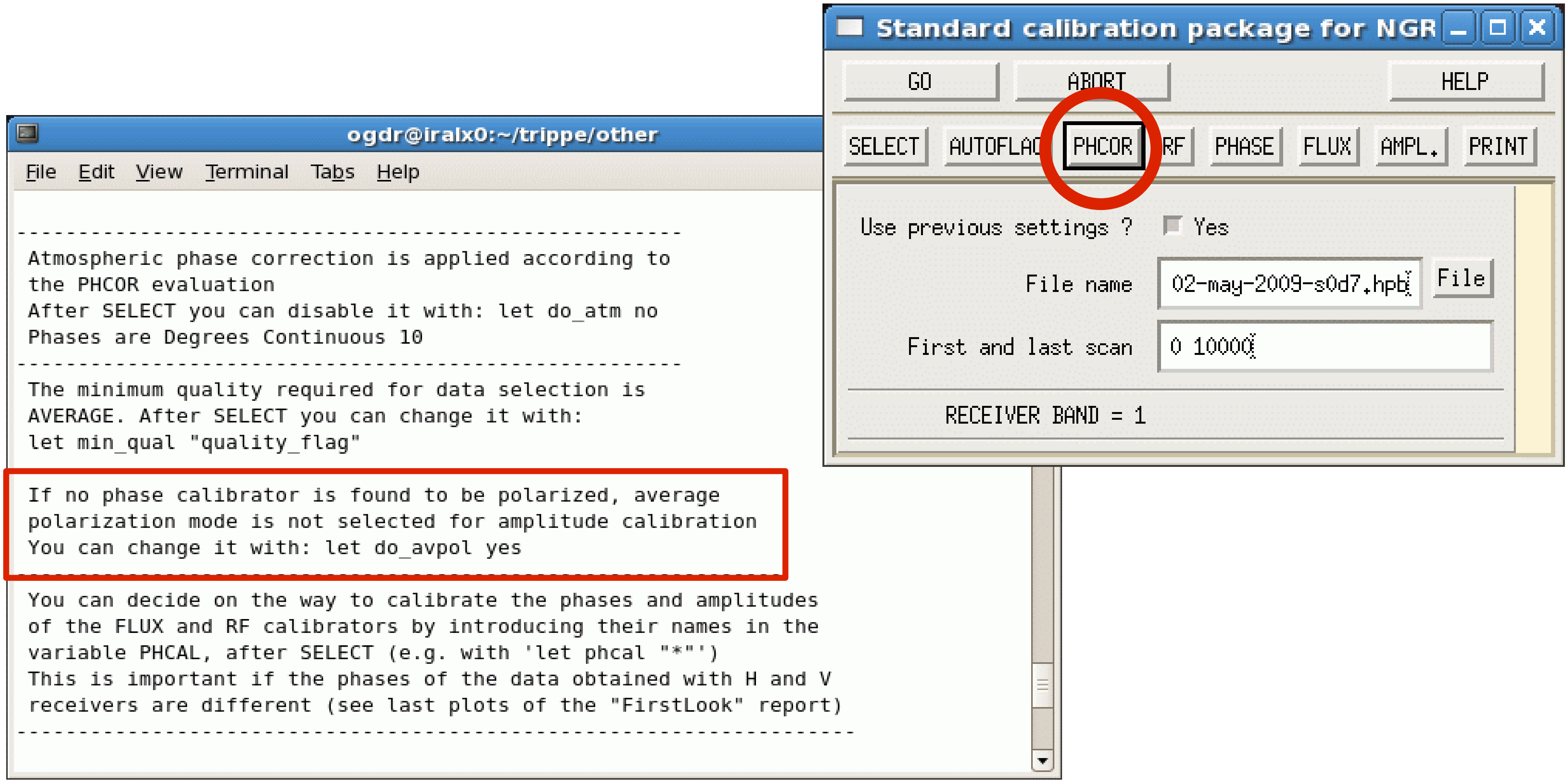
h: hour angle

ψ: parallactic angle

m: polarization fraction

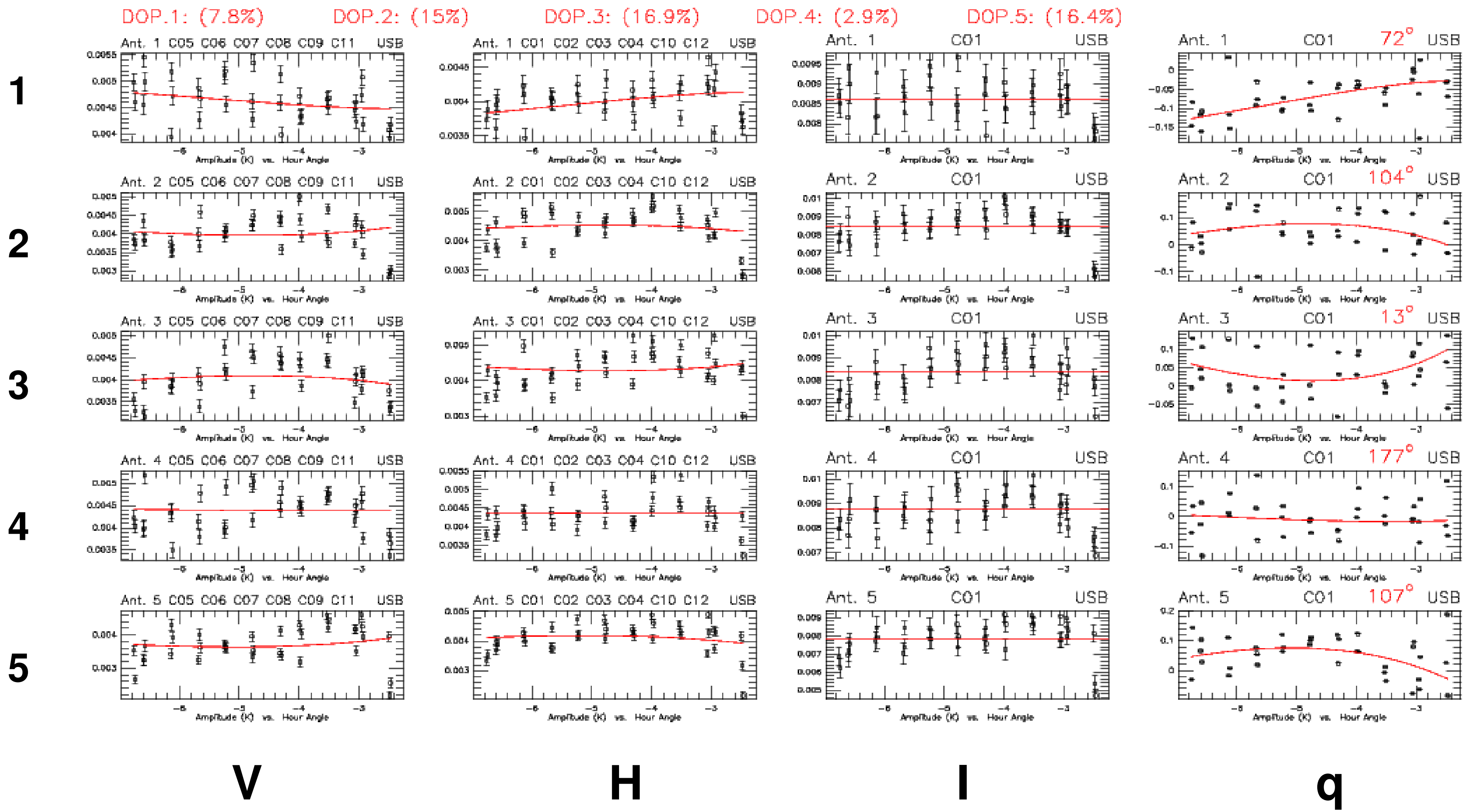
χ: polarization angle

We test the quasar polarization for each track



Decisive CLIC variable: “do_avpol”

A negative test result



Project [redacted]
Observed on 20-SEP-2010 Configuration 5Dq
(N11W08W05N07E03)

Automatic calibration report by CLIC @ x_calib

September 20, 2010

Scan range:	0 to 10000
Use phase correction:	YES (22GHz)
Minimum quality:	AVERAGE
Auto. flag procedure:	YES (0 scans)
WVR interference check:	YES (0 in 267 scans)
Averaged polarization mode for amplitude calibration:	NO

	Receiver 1
Bandpass:	Excellent
Phase:	Good
Seeing HOR:	1.47″
Seeing VER:	1.46″
Amplitude:	Good

1 Summary

1.1 Calibrators

Name	Flux (Jy) @114.1 GHz		Calibration
0923+392	4.31	*Computed*	
3C84	10.70	*Fixed*	*RF*
1146+596	0.15	*Computed*	*phase/amp*

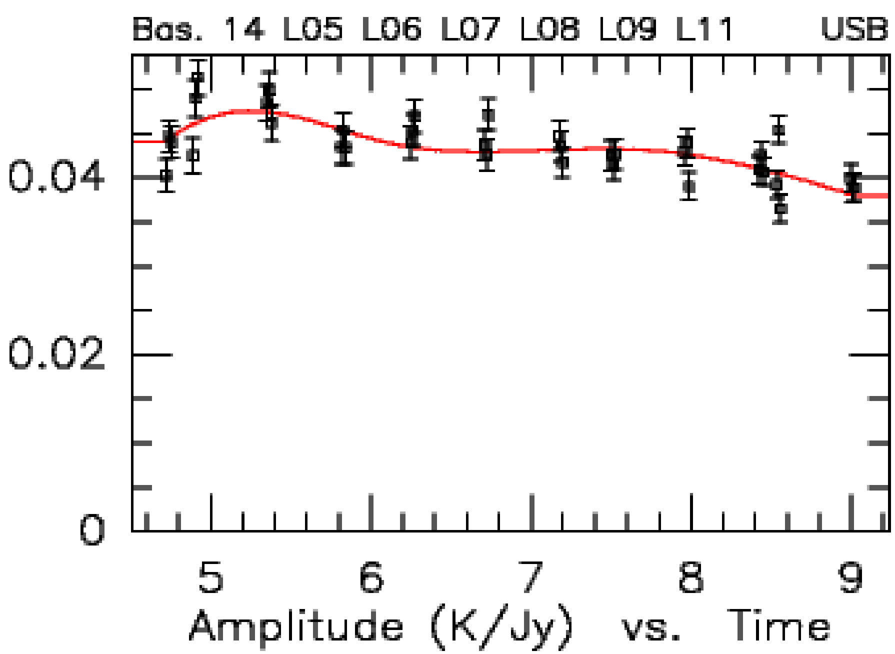
1.2 Efficiencies

Antenna 1 (A1)	25.4	Jy/K	(0.93)
Antenna 2 (A2)	23.7	Jy/K	(0.99)
Antenna 3 (A3)	24.2	Jy/K	(0.98)
Antenna 4 (A4)	23.4	Jy/K	(1.01)
Antenna 5 (A5)	24.4	Jy/K	(0.97)

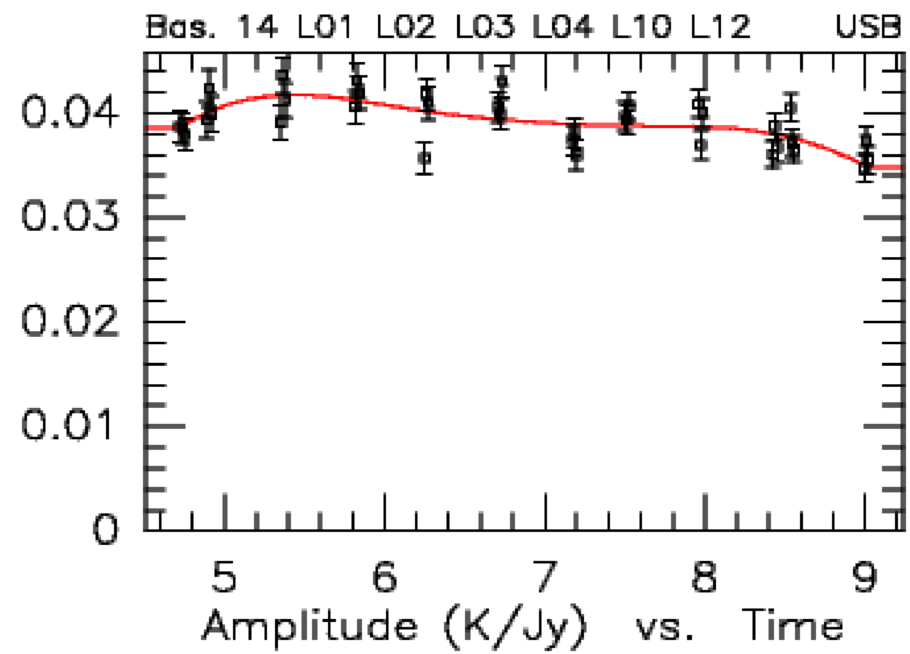
1.3 Observed Source(s)

[redacted] observed for Hour Angles −7.4 to −3.2

2 calibrations for 2 polarizations

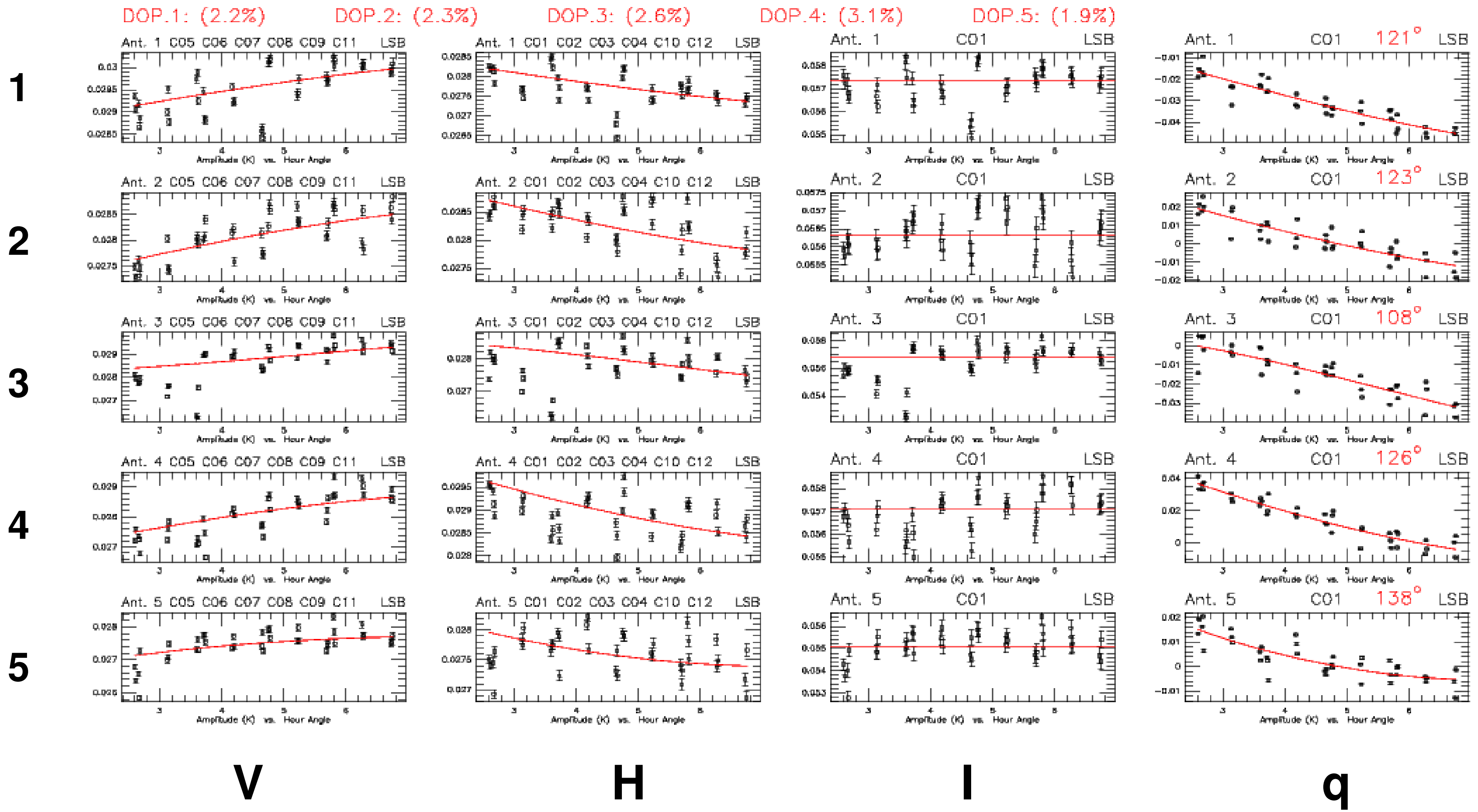


H



V

A positive test result



Project [redacted]
Observed on 19-SEP-2010 Configuration 5Dq
(N11W08W05N07E03)

Automatic calibration report by CLIC @ x_calib

September 19, 2010

Scan range:	0 to 10000
Use phase correction:	YES (22GHz)
Minimum quality:	AVERAGE
Auto. flag procedure:	YES (0 scans)
WVR interference check:	YES (0 in 295 scans)
Averaged polarization mode for amplitude calibration:	YES

	Receiver 1
Bandpass:	Excellent
Phase:	Excellent
Seeing HOR:	0.96″
Seeing VER:	0.96″
Amplitude:	Excellent

1 Summary

1.1 Calibrators

Name	Flux (Jy) @ 90.2 GHz		Calibration	
MWC349	1.13	*Fixed (model = 1.13)*		
1749+096	2.72	*Computed*		
1418+546	0.69	*Computed*	*phase/amp*	*(detected polarization)*
3C454.3	33.95	*Computed*	*RF*	

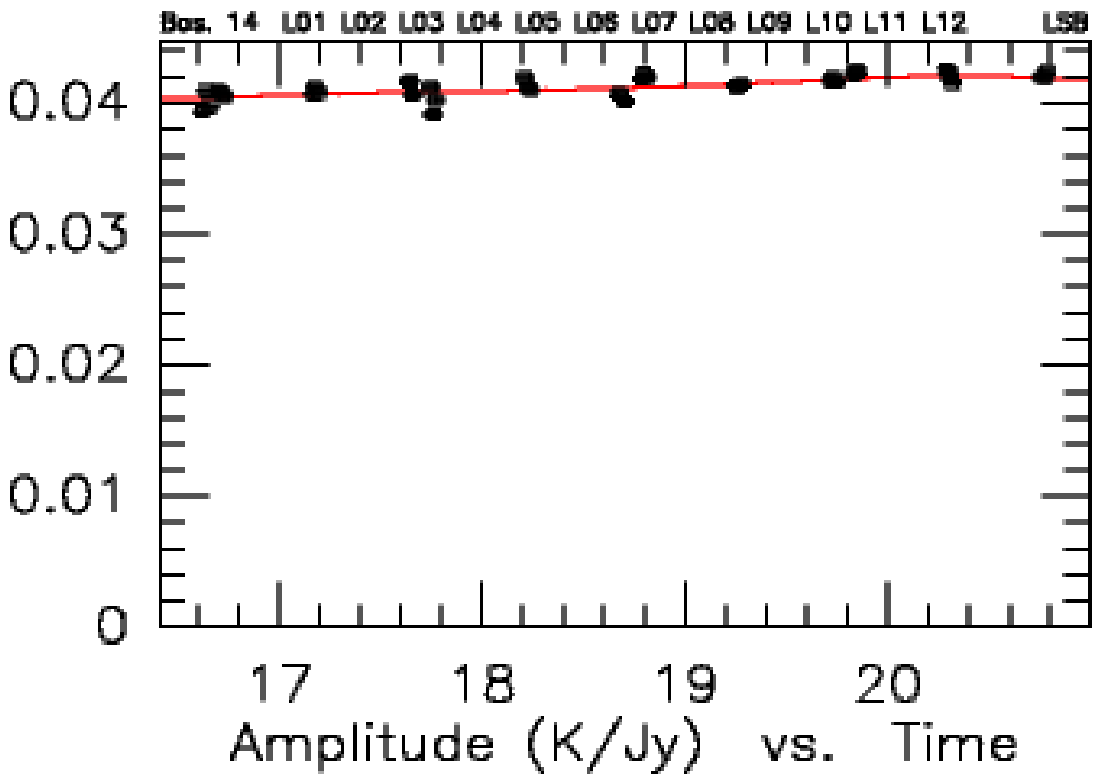
1.2 Efficiencies

Antenna 1 (A1)	25.0	Jy/K	(0.87)
Antenna 2 (A2)	24.7	Jy/K	(0.88)
Antenna 3 (A3)	23.7	Jy/K	(0.92)
Antenna 4 (A4)	24.8	Jy/K	(0.88)
Antenna 5 (A5)	26.0	Jy/K	(0.84)

1.3 Observed Source(s)

[redacted] observed for Hour Angles 2.7 to 6.7

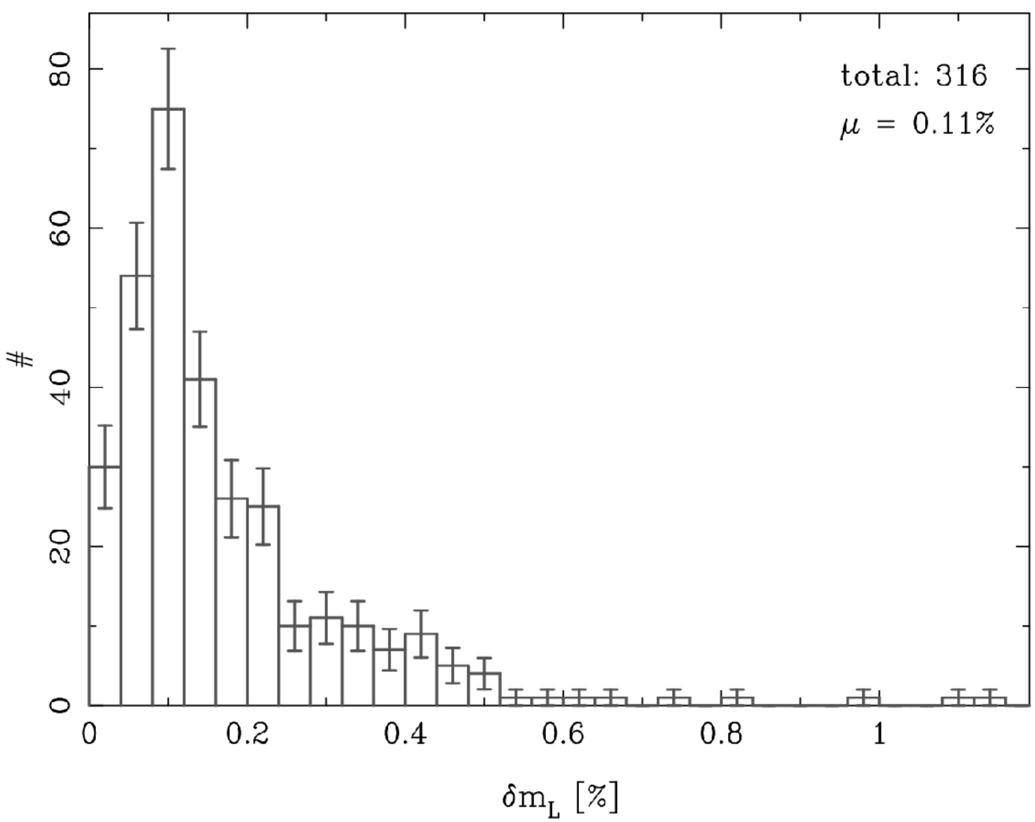
1 calibration for $I = H + V$



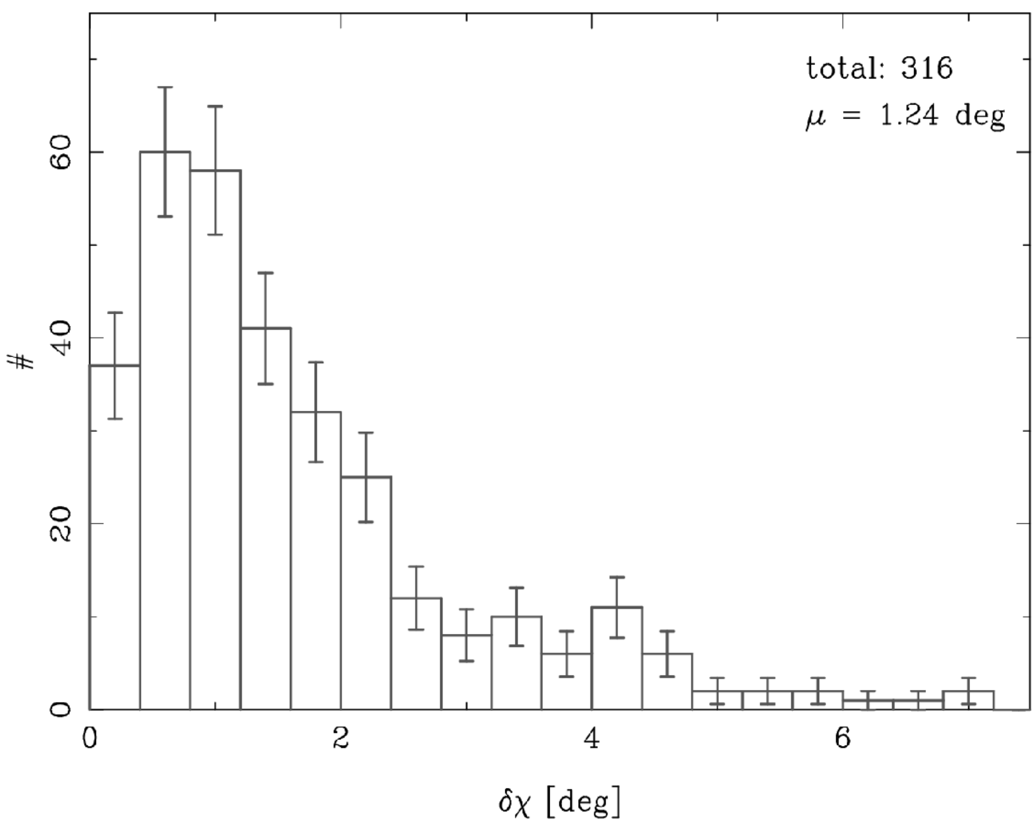
I

Statistical accuracies are very good

degree of polarization



polarization angle

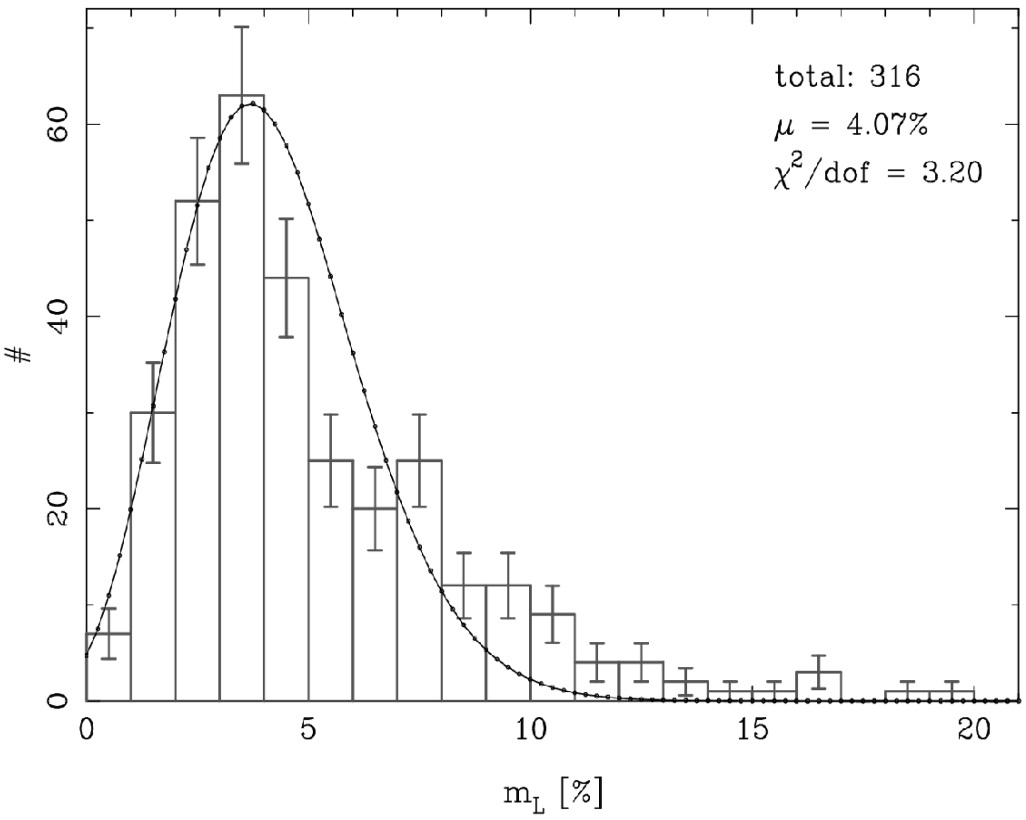


median δm : ~0.1%

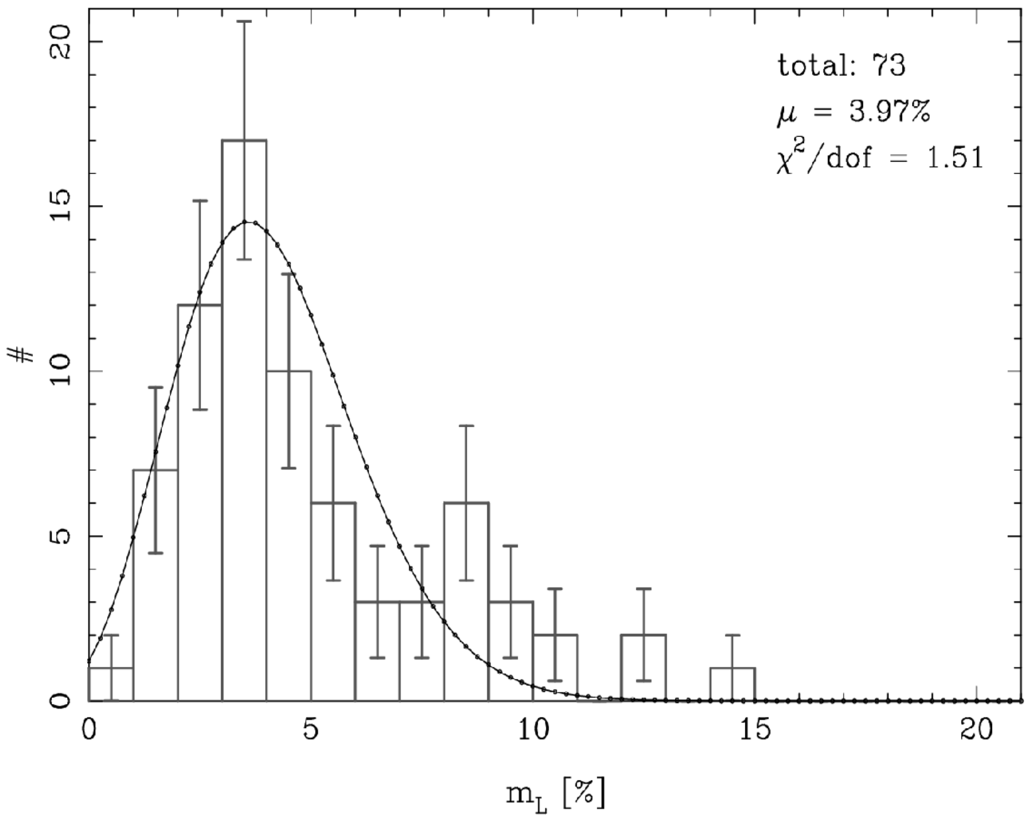
median $\delta\chi$: ~1°

We see polarization (almost) everywhere

all measurements

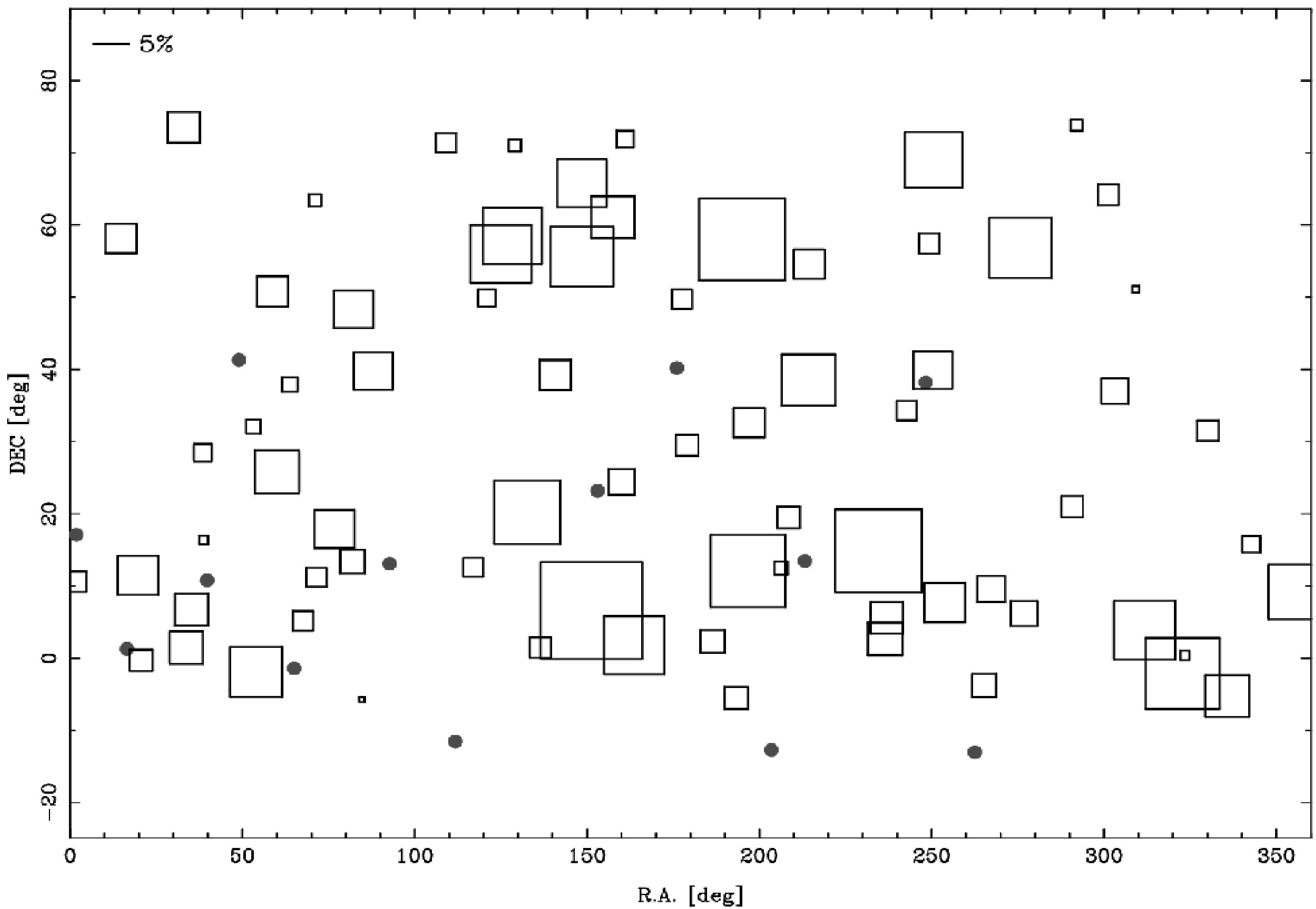


one value per target

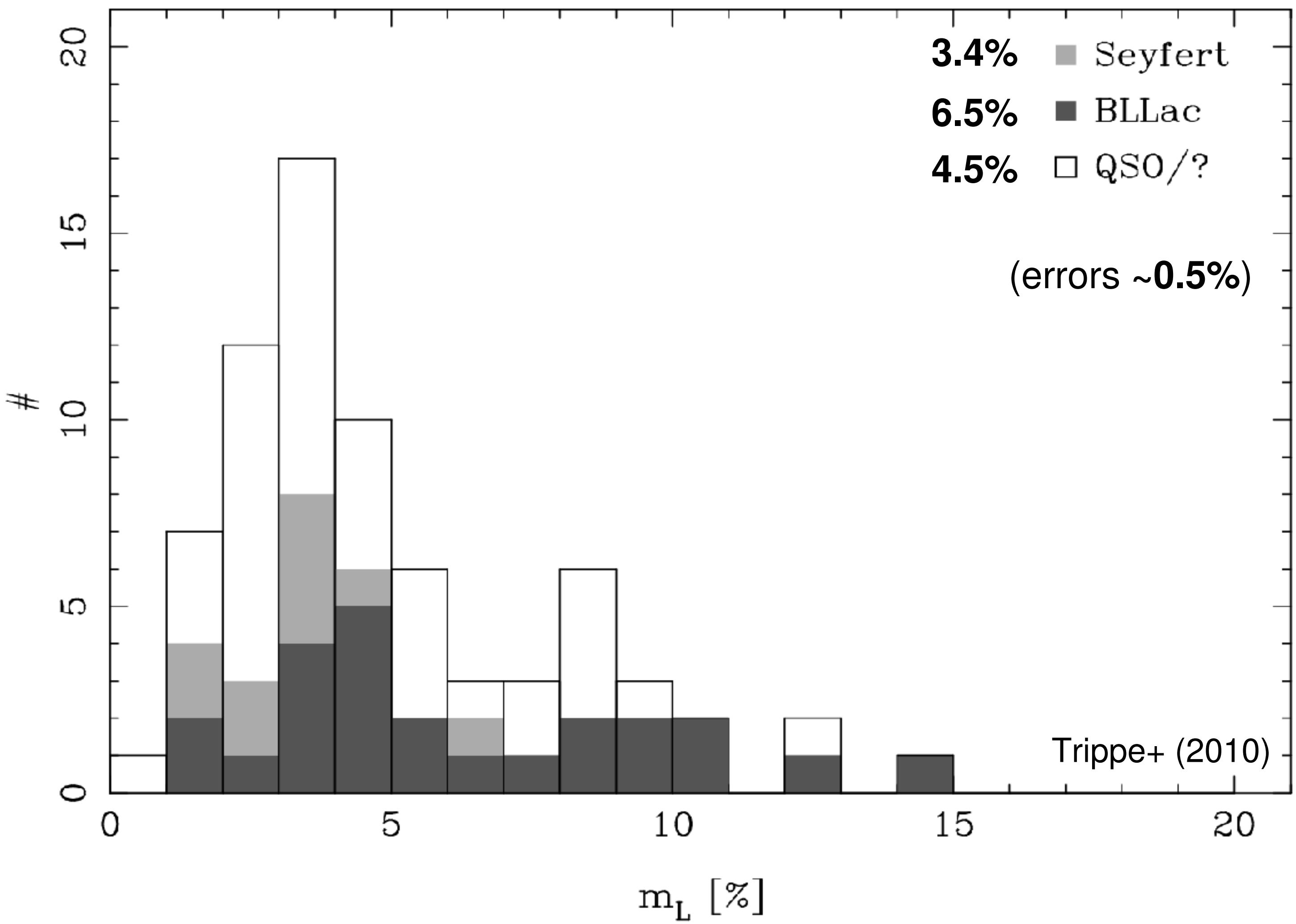


316 out of 441 measurements (73 out of 86 QSOs) detect polarization

We see polarization (almost) everywhere

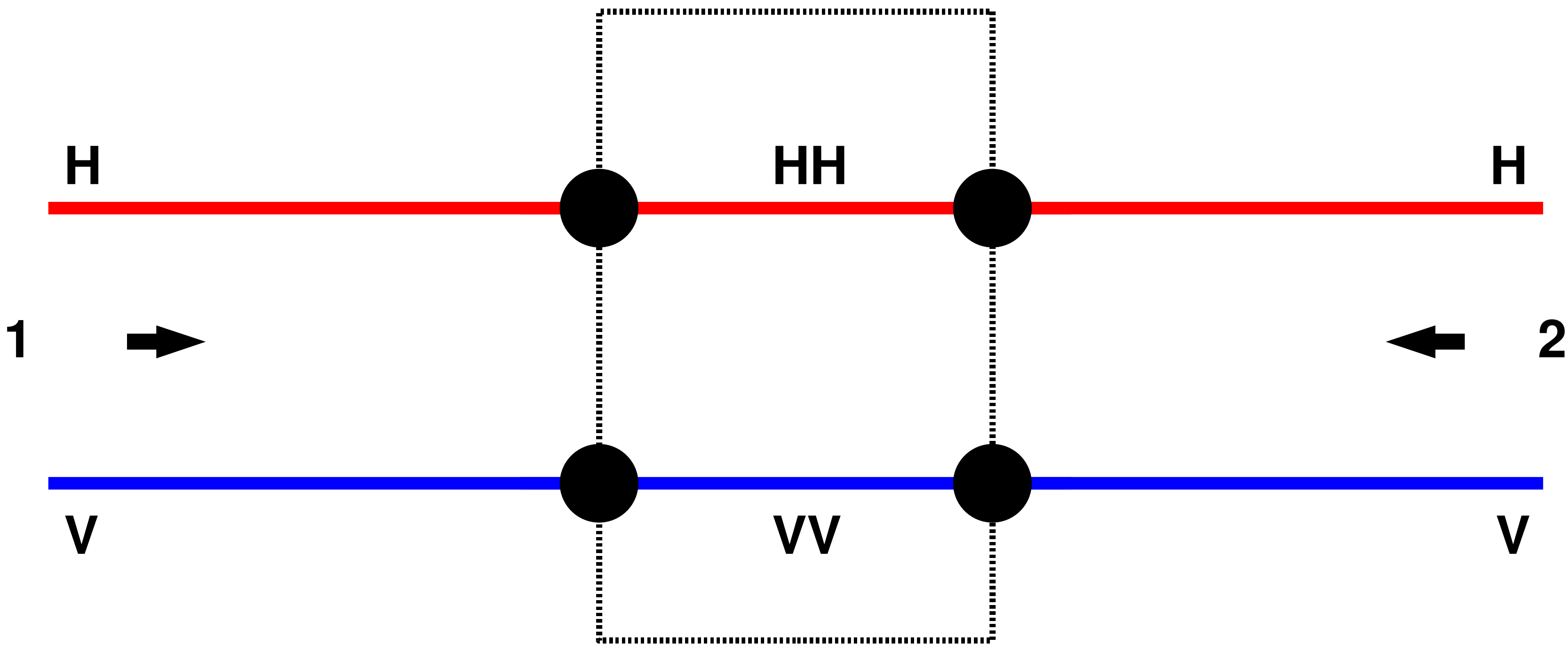


Different source types are slightly different



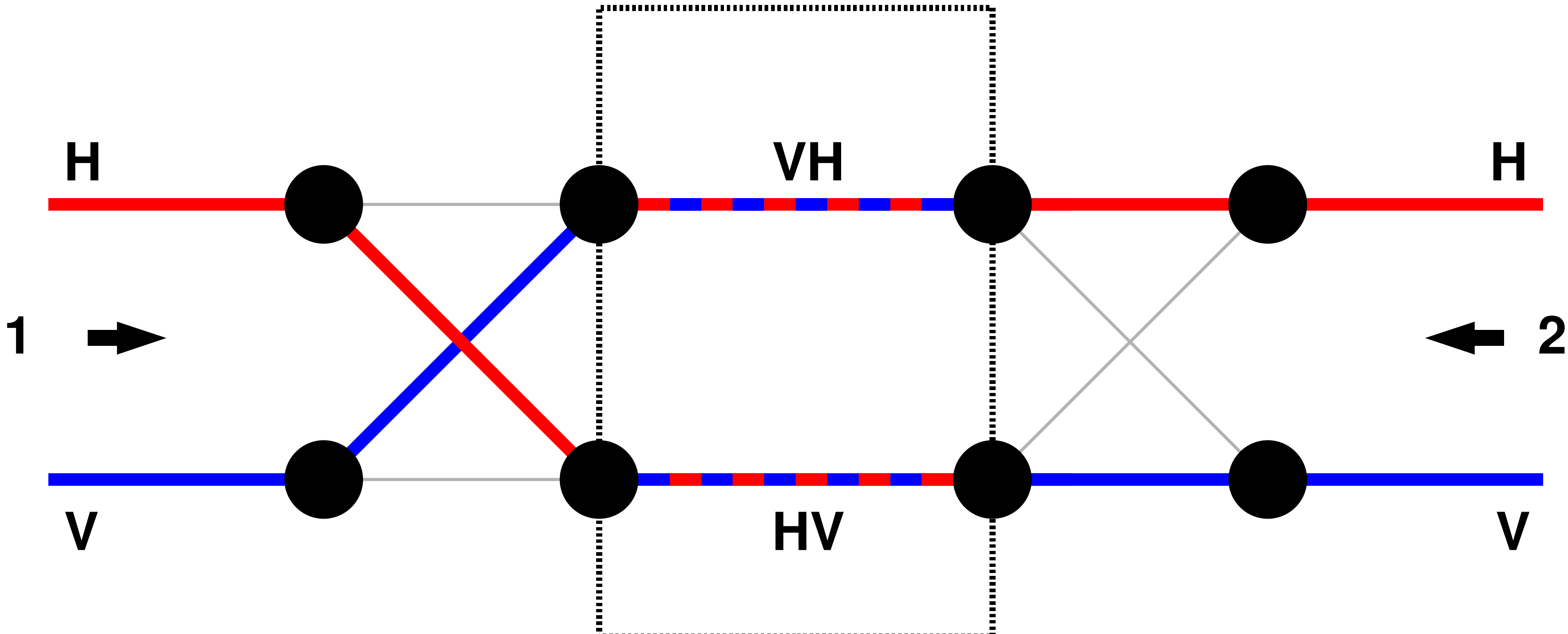
No dichotomy radio loud vs. radio quiet ➔ similar emission region properties

PdBI, present day:
Only parallel-hand correlations



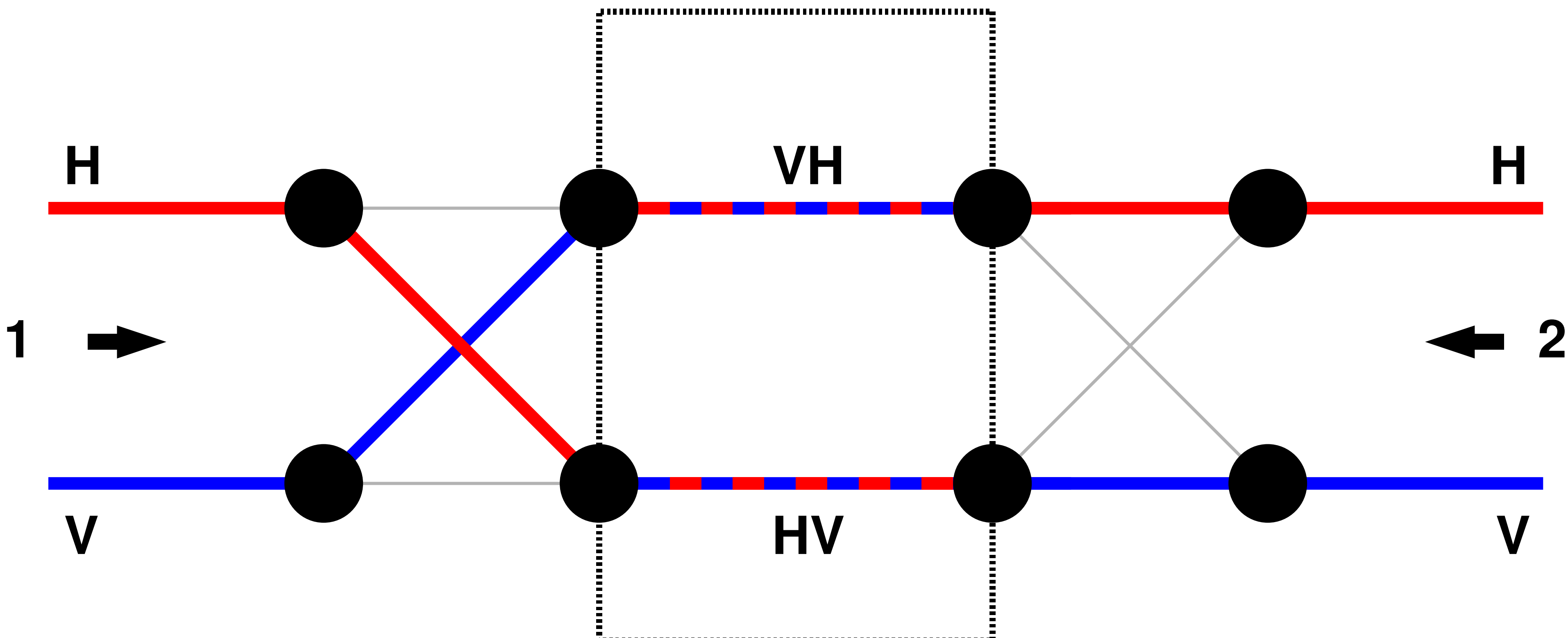
PdBI, 2010/2011:

Also cross-polarization correlations

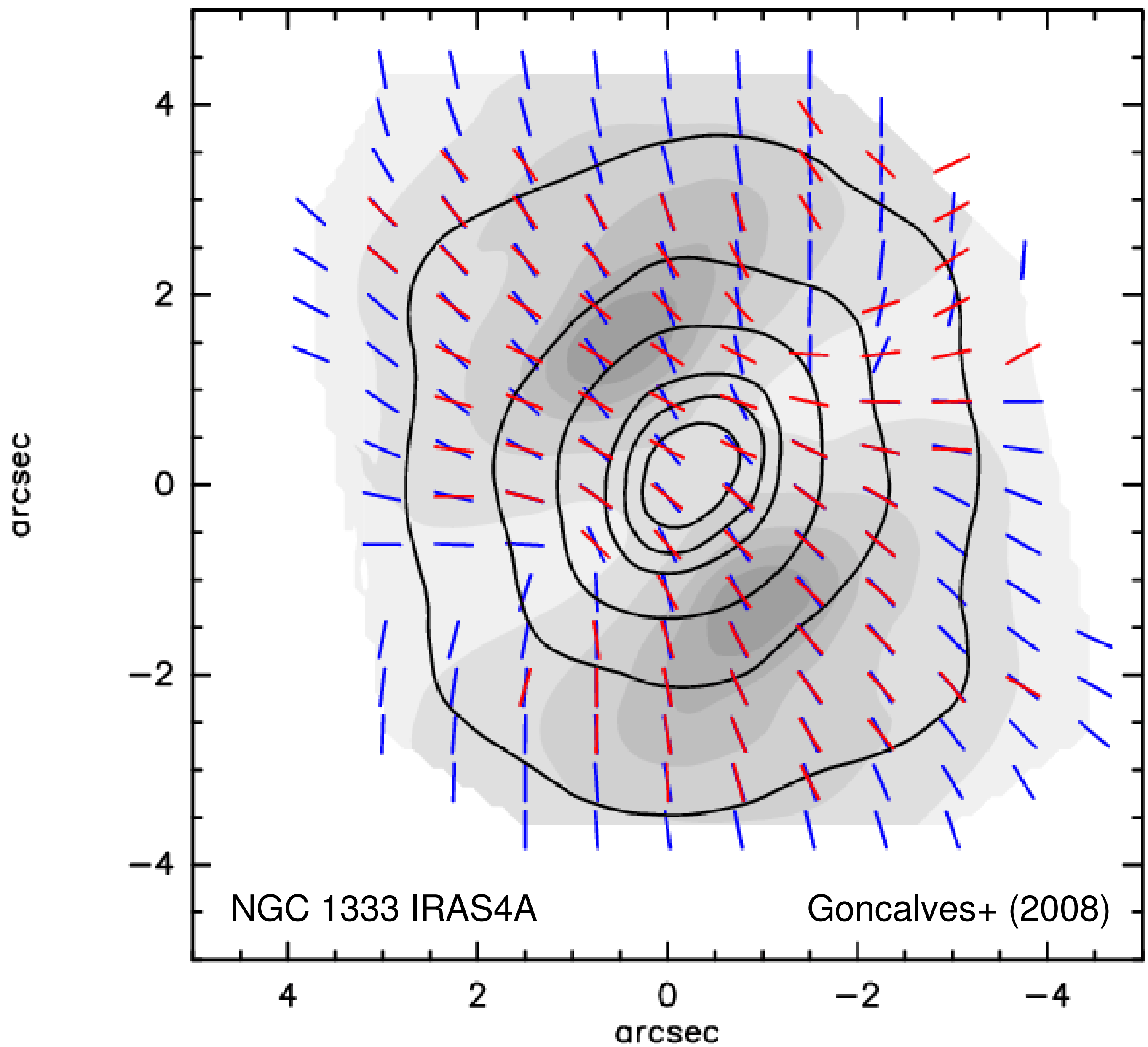


PdBI, 2010/2011:
Also cross-polarization correlations

6 antennas ➔ 8 configurations for one full cycle



The goal: polarimetric mapping



Summary

- The PdBI uses dual linear polarization receivers → observations are sensitive to source and calibrator polarization
- Only parallel-hand polarizations correlated → Earth rotation polarimetry
- Check calibrator polarization for each track in order to prevent systematic errors
- AGN monitoring finds that most sources are polarized with *m* ~ 1 – 19%
- PdBI prepared for full Stokes polarimetry → polarimetric mapping