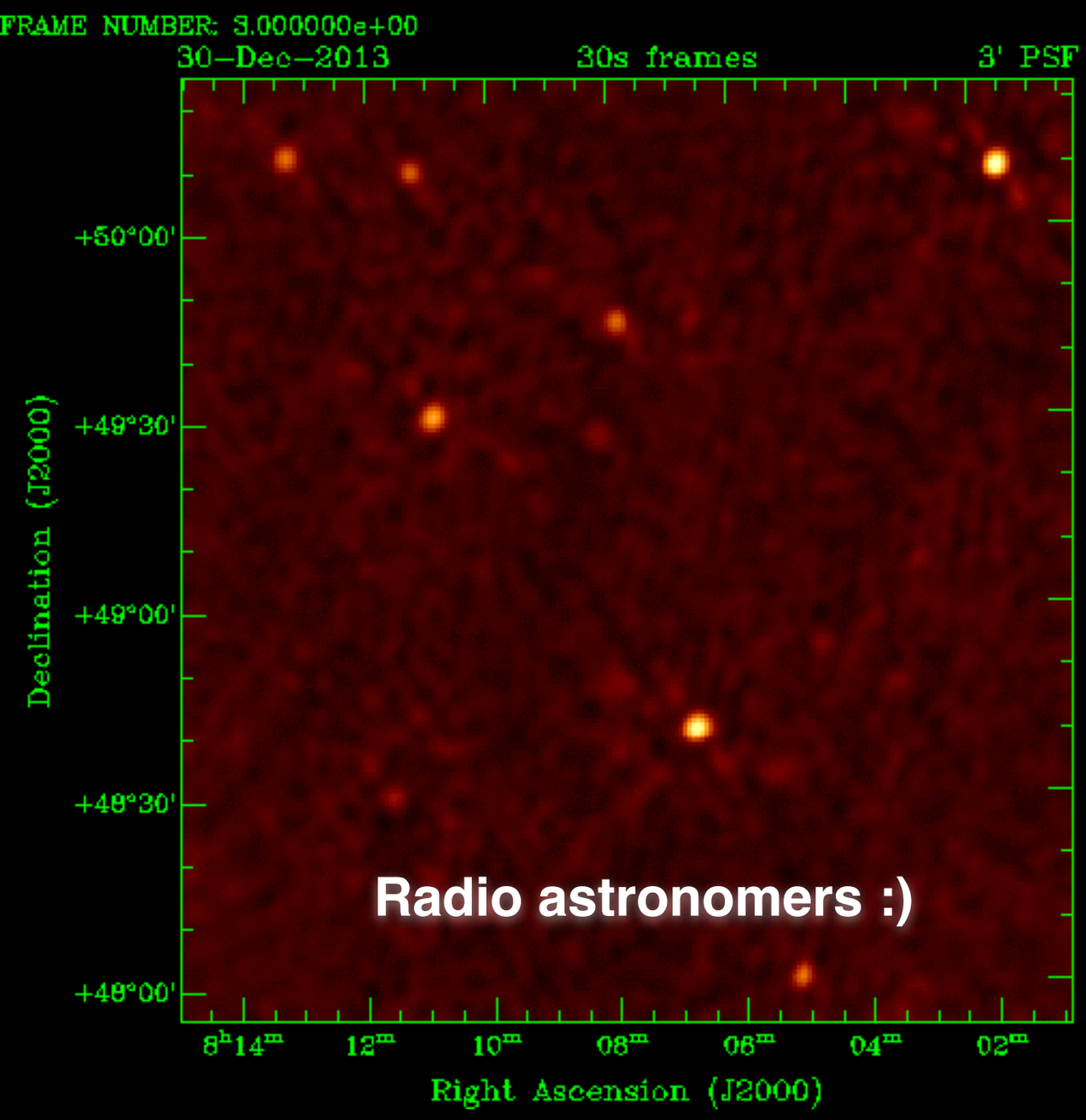
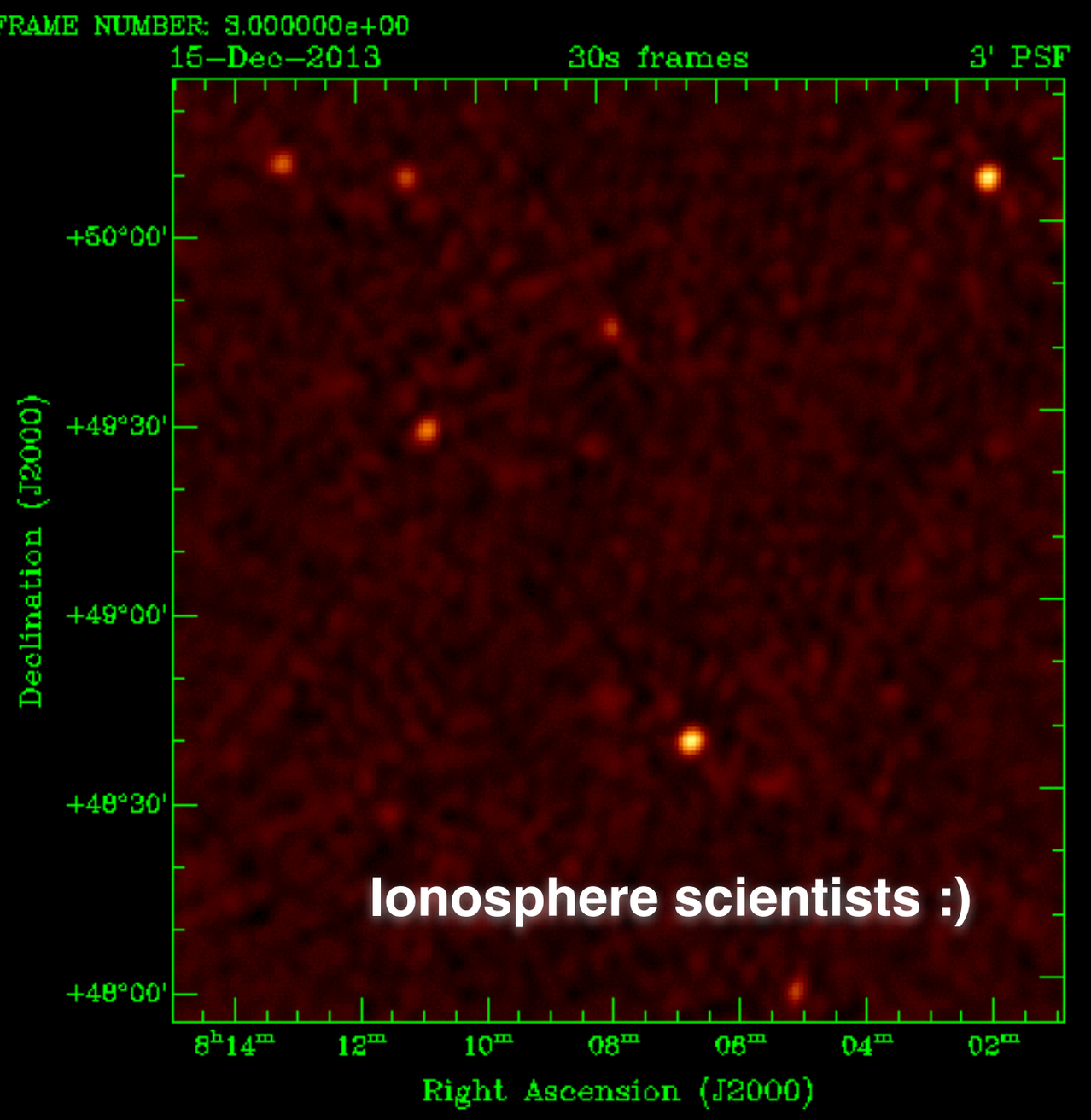
Interferometric observations at 60 MHz: the effect of the ionosphere





Francesco de Gasperin

2/6/16 - Warsaw

Radio Interferometers record

1. **Differential phases**
   (on scales 100 m -> 100 km)
2. **Amplitudes**
3. **Polarisation information**

Phases RR

(amp/ph GAIN on a strong calibrator)

Freq (20-70 MHz) >>

Decent ionospheric condition / 100 km baseline:

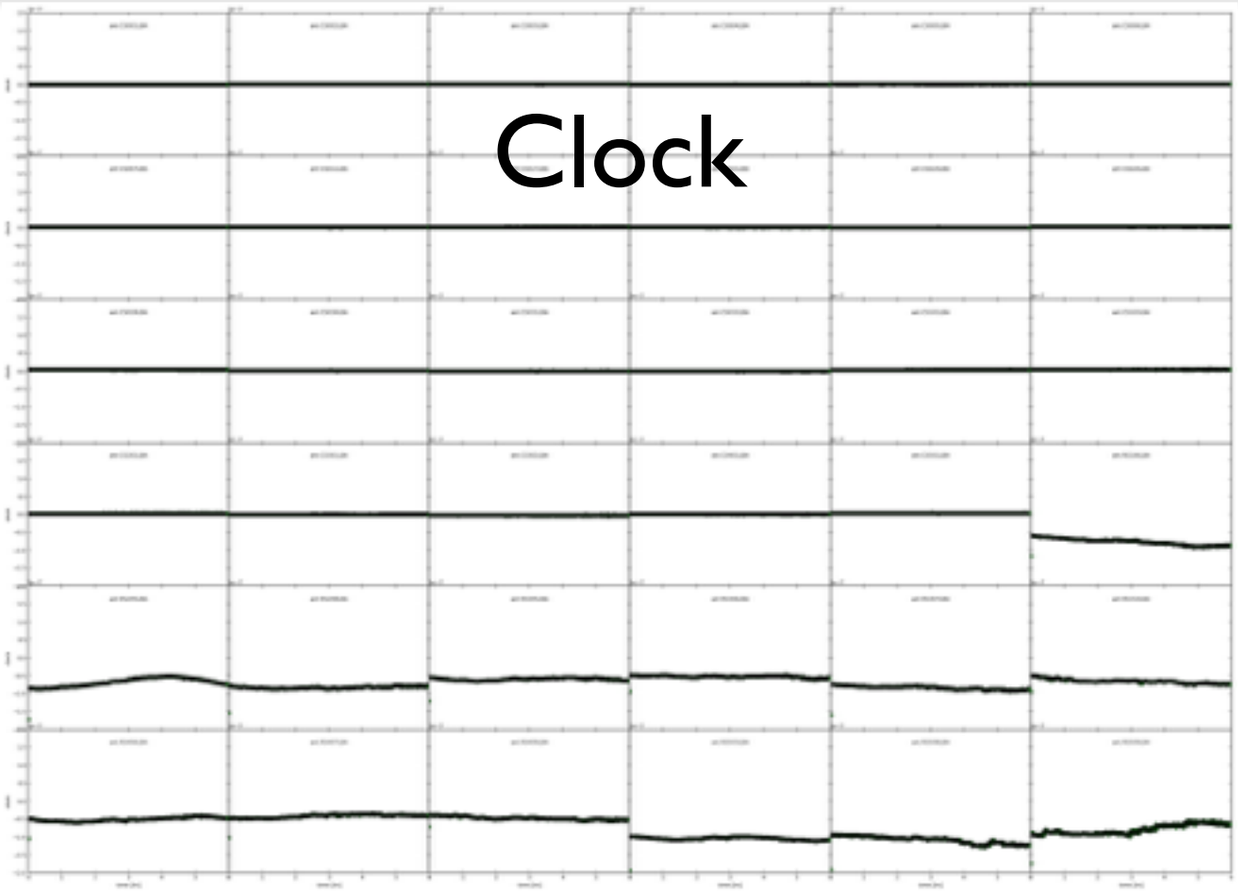
- Min freq resolution: 50 kHz
- Min time resolution: 5 sec

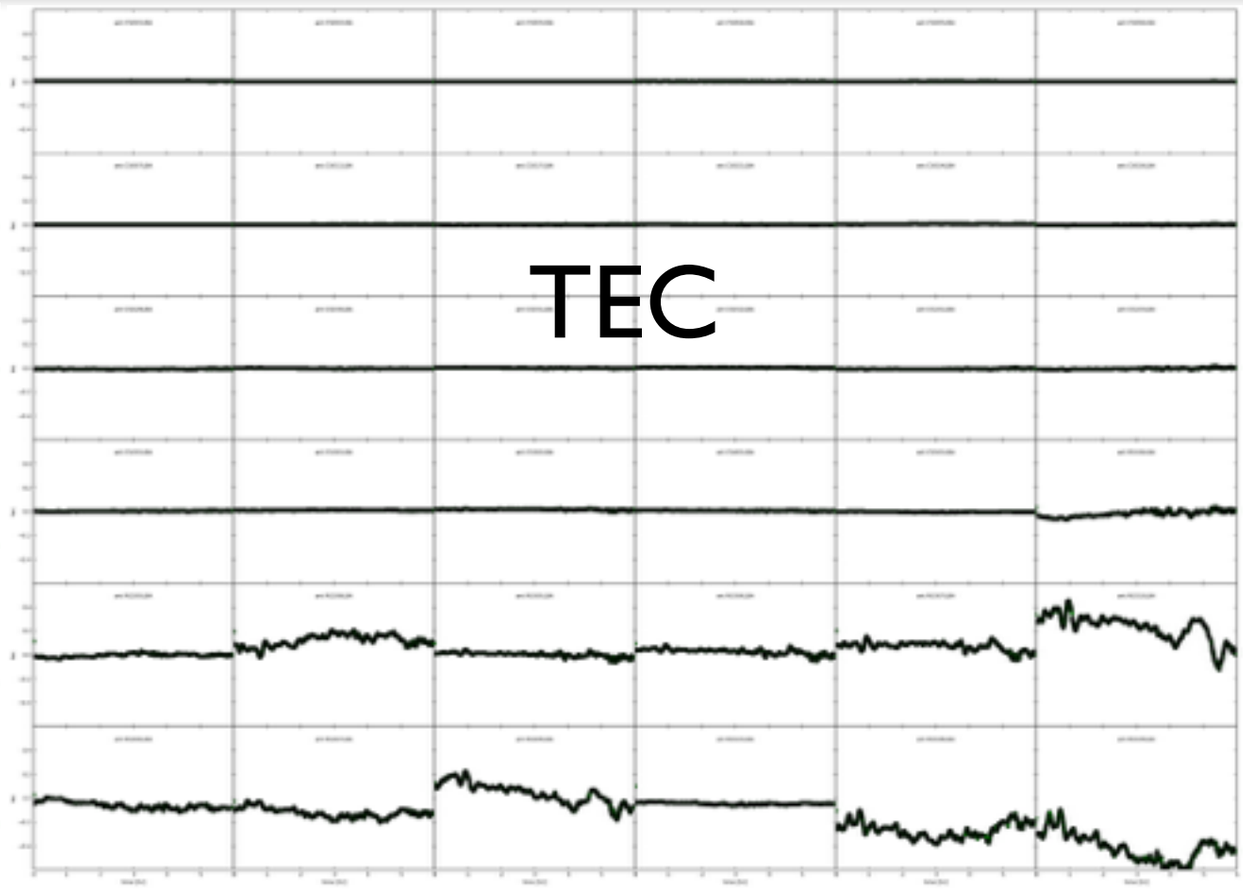
Time (6h) >>

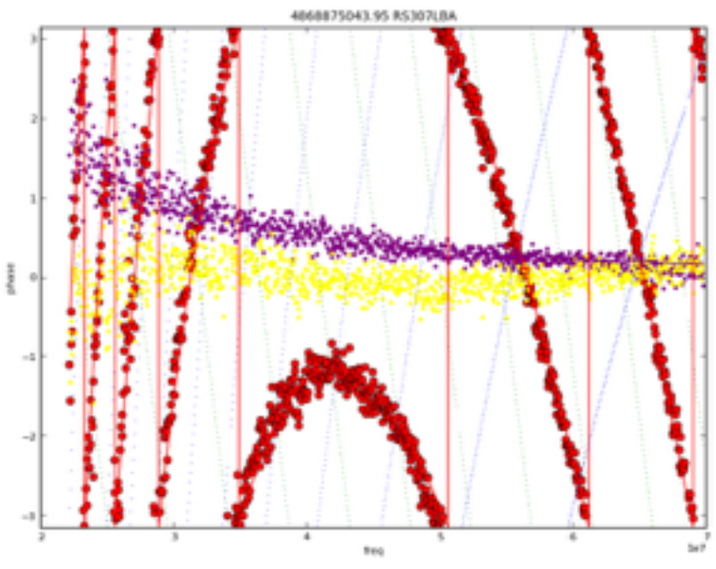
Clock drift & Ionospheric delay

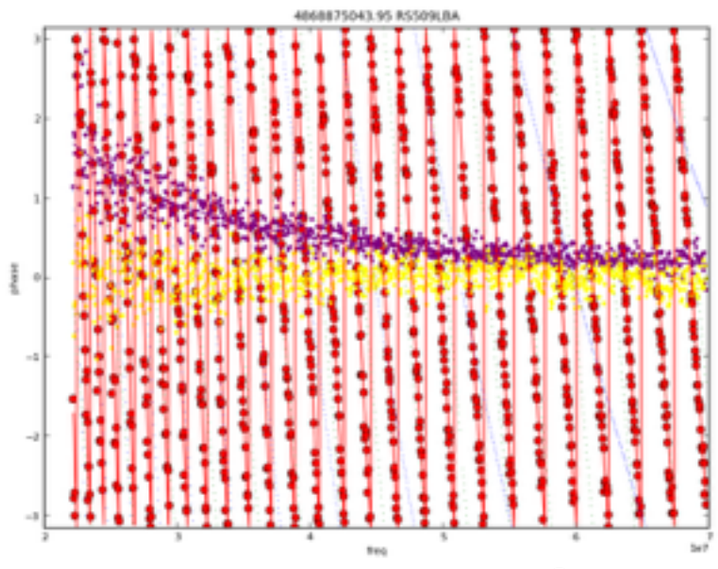
	Clock drift	Ionospheric delay
Affects	Phase	Phase
Type	Scalar	Scalar
Freq. dep.	$\propto$ f	$\propto$ 1/f
Dir. dep.	No	Yes (tens arcmin)

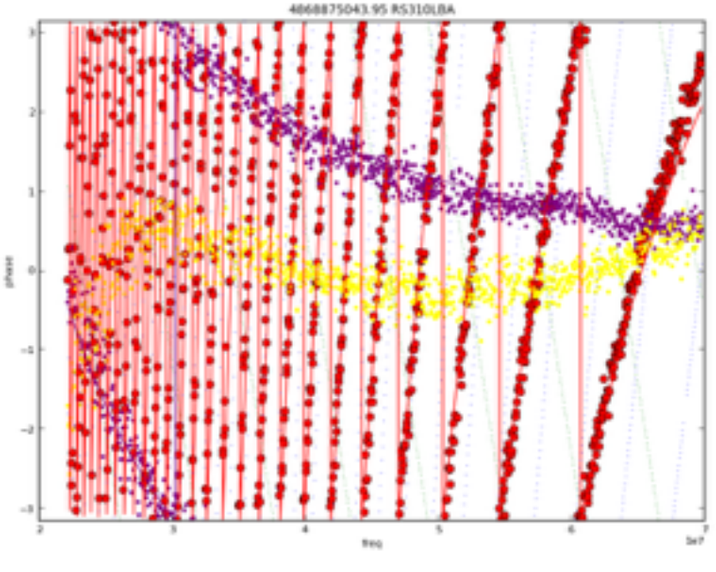
Clock/TEC separation









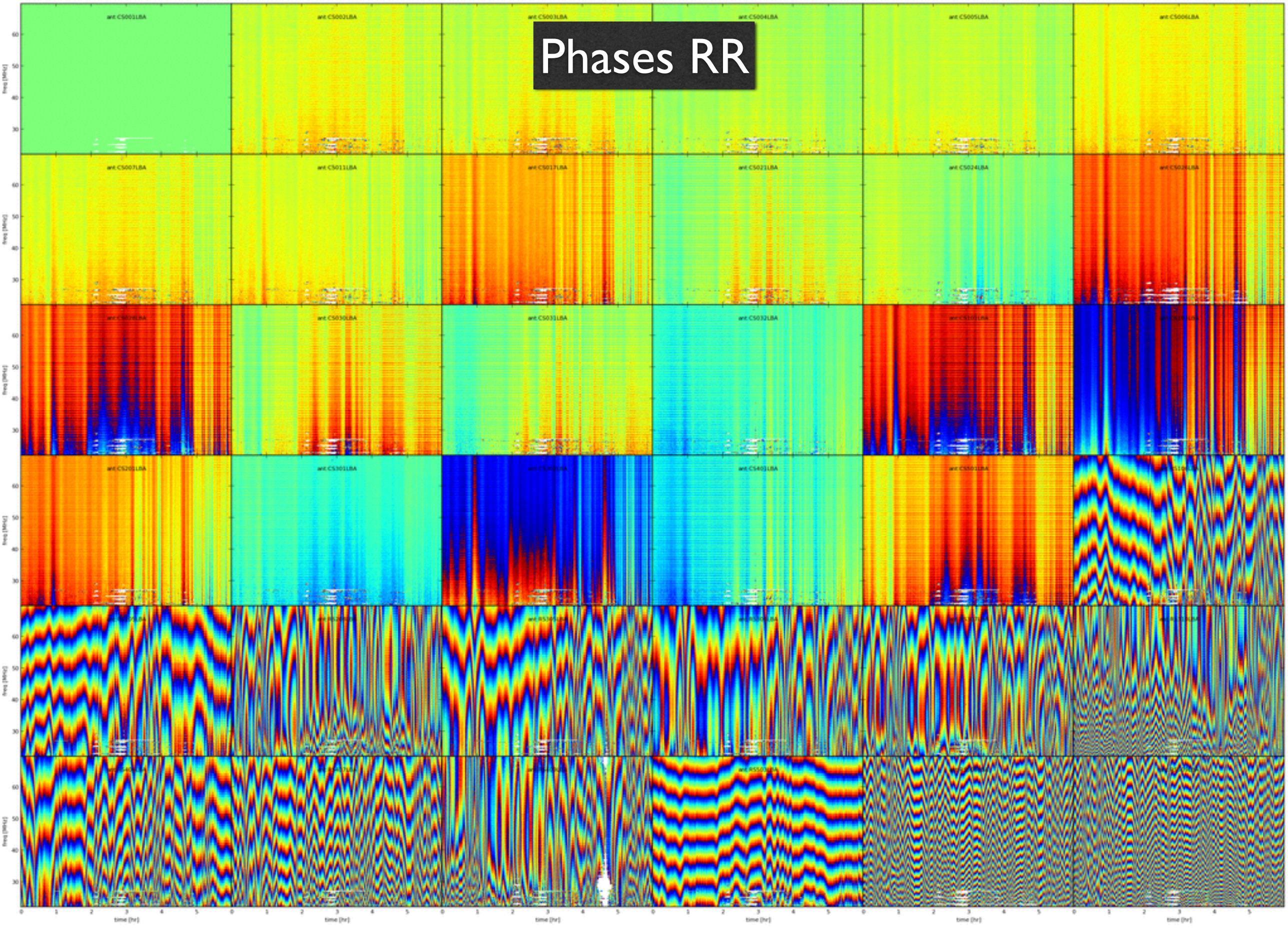


$$\Delta\theta = 2\pi f \Delta t + 8.44797245 \times 10^9 \Delta TEC/f + \Delta\theta_0$$

Faraday rotation

	Clock drift	Ionospheric delay	Faraday rotation
Affects	Phase	Phase	Phase (circ) Amp+Ph (lin)
Type	Scalar	Scalar	Diag (circ) Rot (lin)
Freq. dep.	$\propto f$	$\propto 1/f$	$\propto 1/f^2$
Dir. dep.	No	Yes (tens arcmin)	Yes (degrees)

Phases RR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ant:CS004LBA
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ant:CS006LBA
ant:CS007LBA
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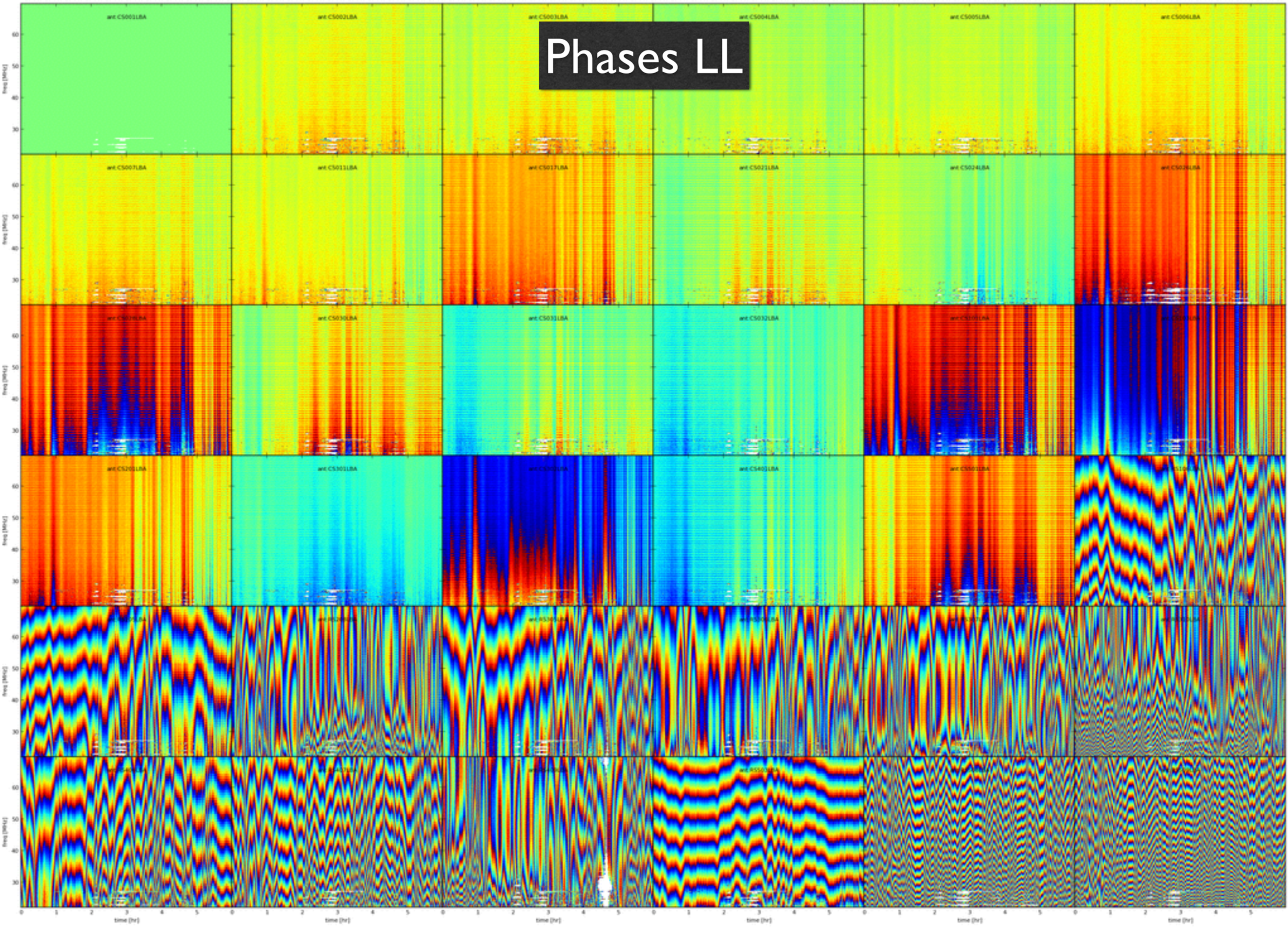
ant:CS017LBA
ant:CS021LBA
ant:CS024LBA
ant:CS026LBA
ant:CS028LBA
ant:CS030LBA
ant:CS031LBA
ant:CS032LBA
ant:CS101LBA
ant:CS201LBA
ant:CS301LBA
ant:CS302LBA
ant:CS401LBA
ant:CS501LBA
freq [MHz]
time [hr]

Phases LL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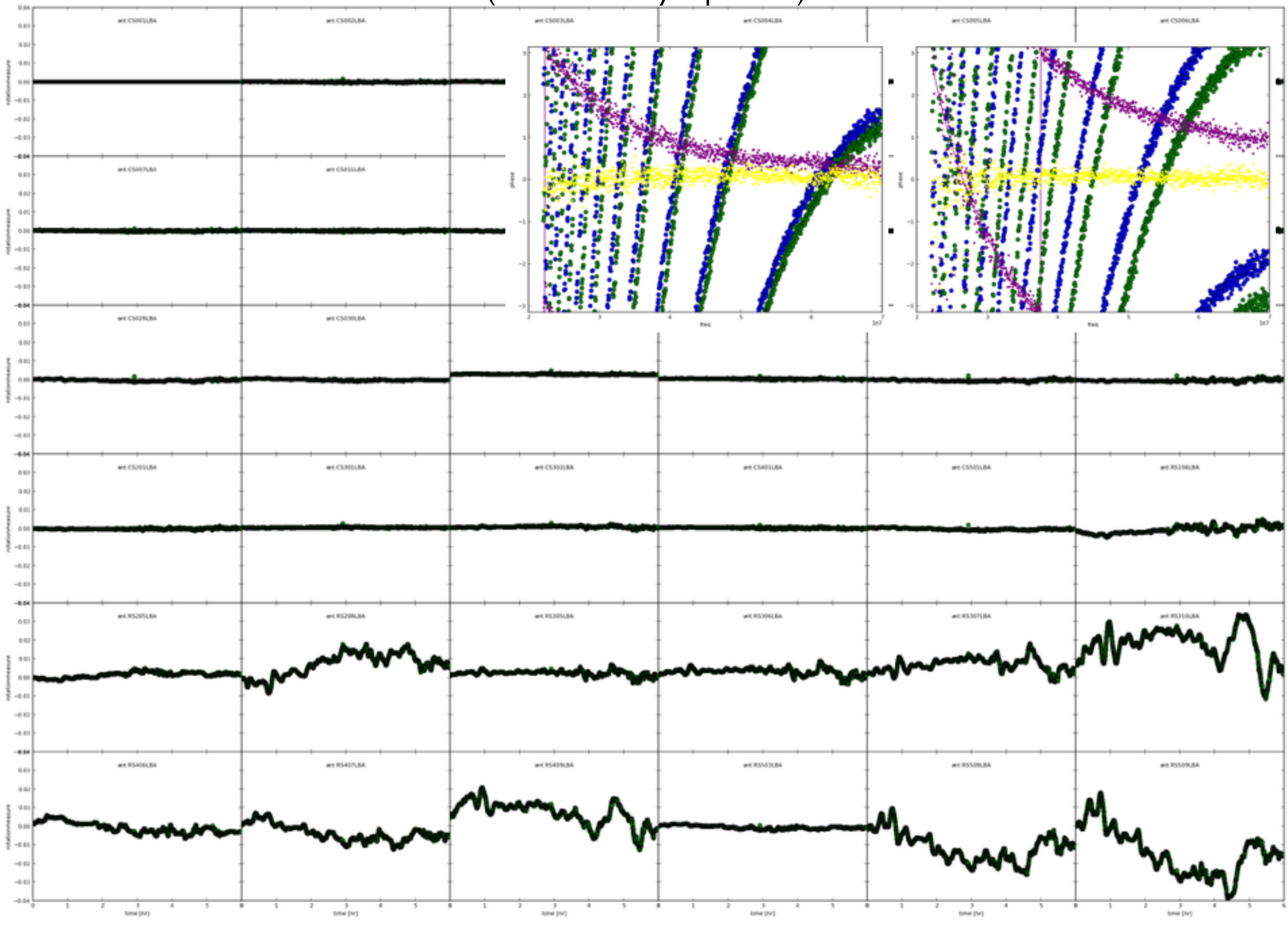
ant:CS017LBA
ant:CS021LBA
ant:CS024LBA
ant:CS028LBA
ant:CS030LBA
ant:CS031LBA
ant:CS032LBA
ant:CS201LBA
ant:CS301LBA
ant:CS401LBA
freq [MHz]
time [hr]

Rotation Measure

(LoSoTo "faraday" operation)



RR

- clock

↓ - TEC - FR

↓ - FR

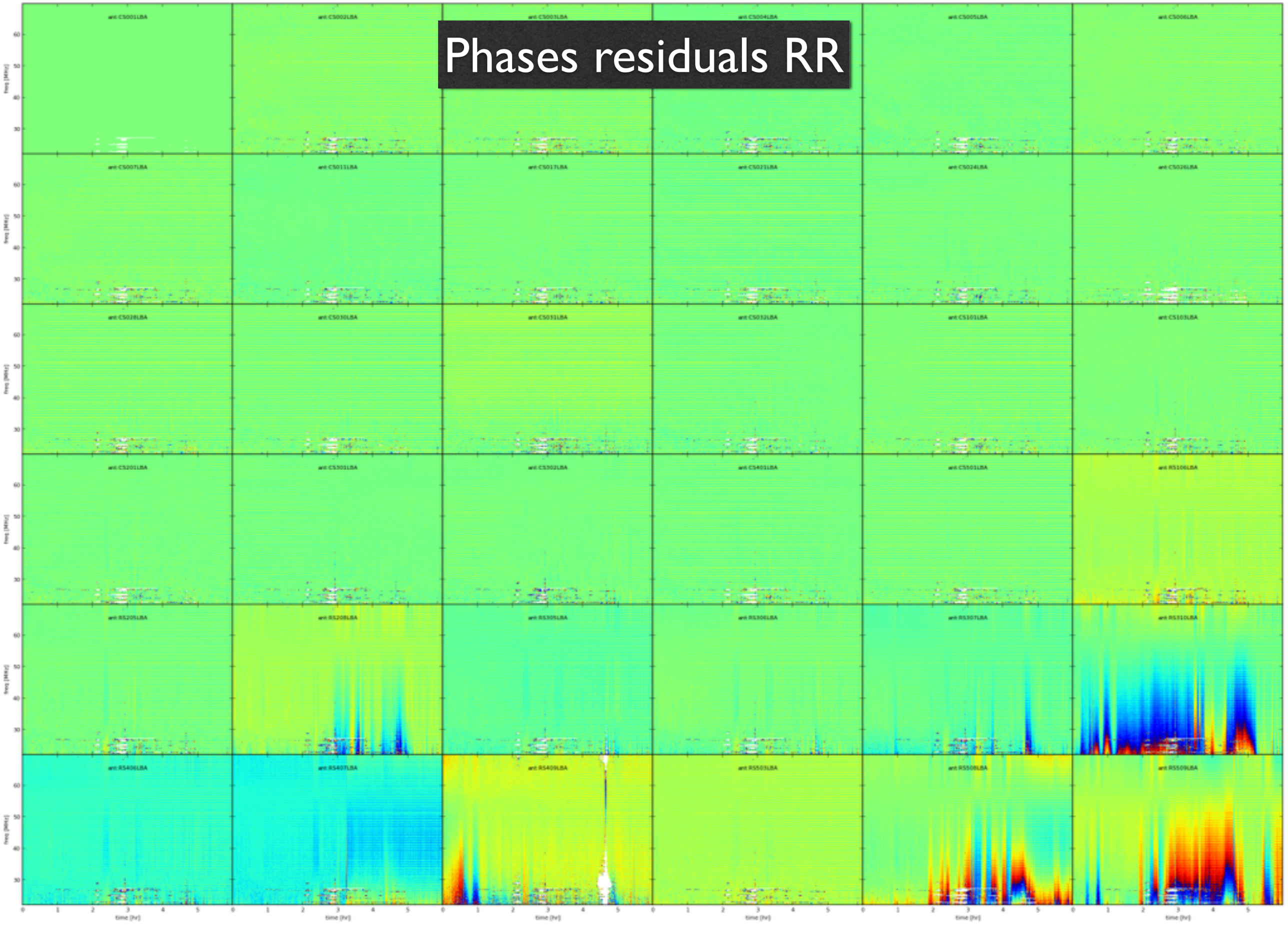
LL

→ - clock

↓ - TEC - FR

↓ - FR

Phases residuals RR



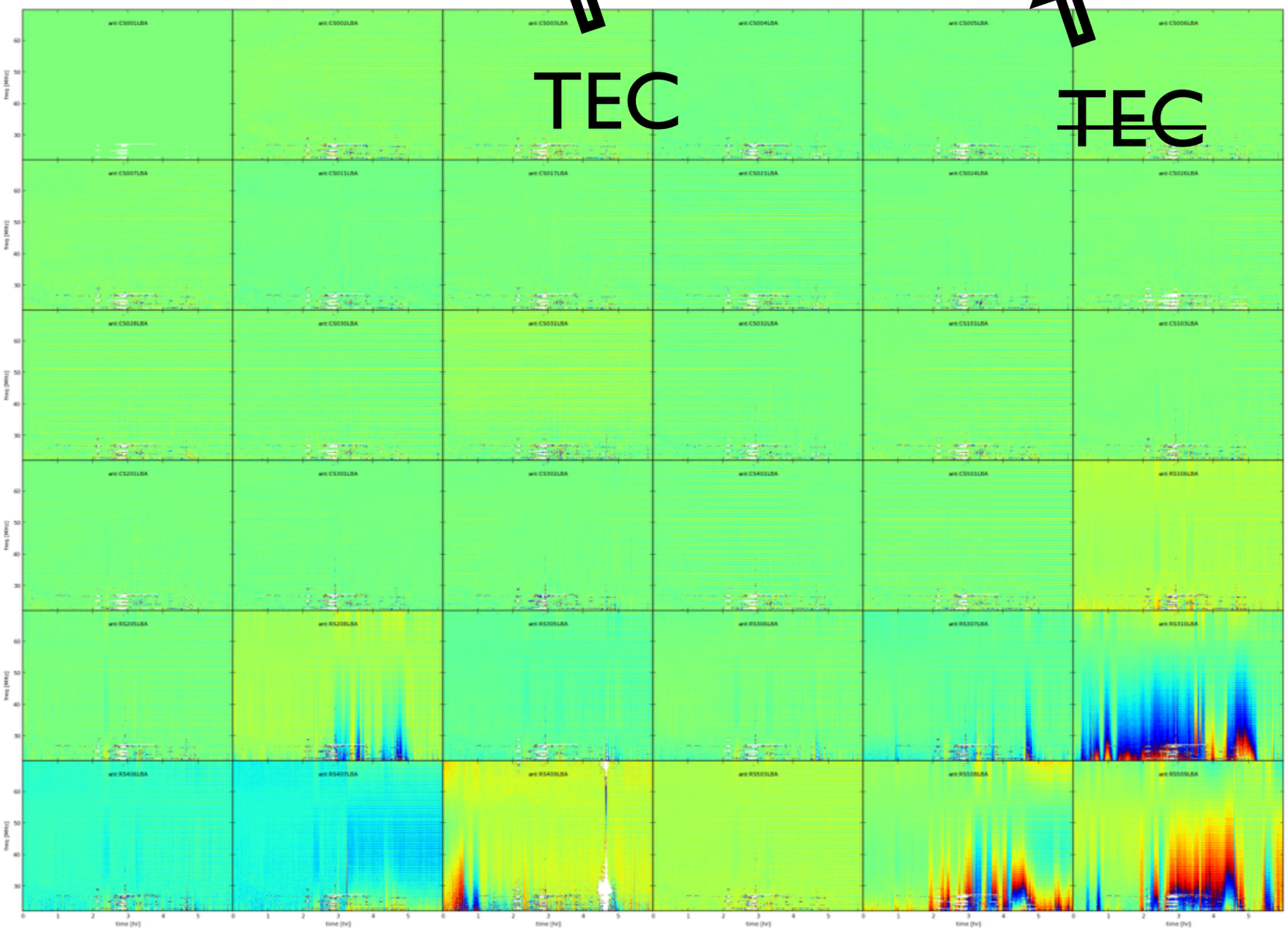
Higher orders

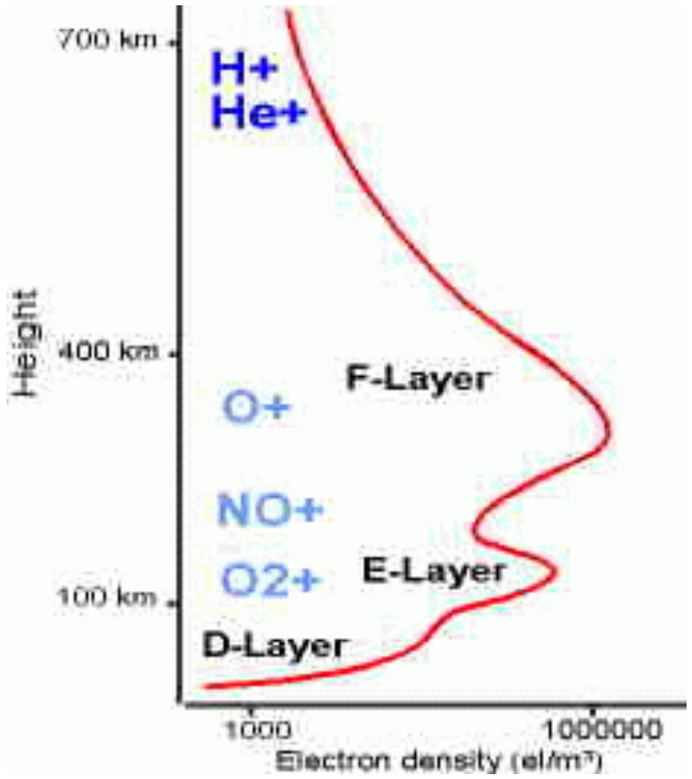
I order II order III order

$$\iota \approx \frac{\kappa}{c\nu^2}\int_0^d n_{\mathrm{e}}(x)\,\mathrm{d}x. + \frac{3\kappa^2}{2c\nu^4}\int_0^d n_{\mathrm{e}}^2(x)\,\mathrm{d}x. + \frac{5\kappa^3}{2c\nu^6}\int_0^d n_{\mathrm{e}}^3(x)\,\mathrm{d}x. + \cdots.$$

TEC

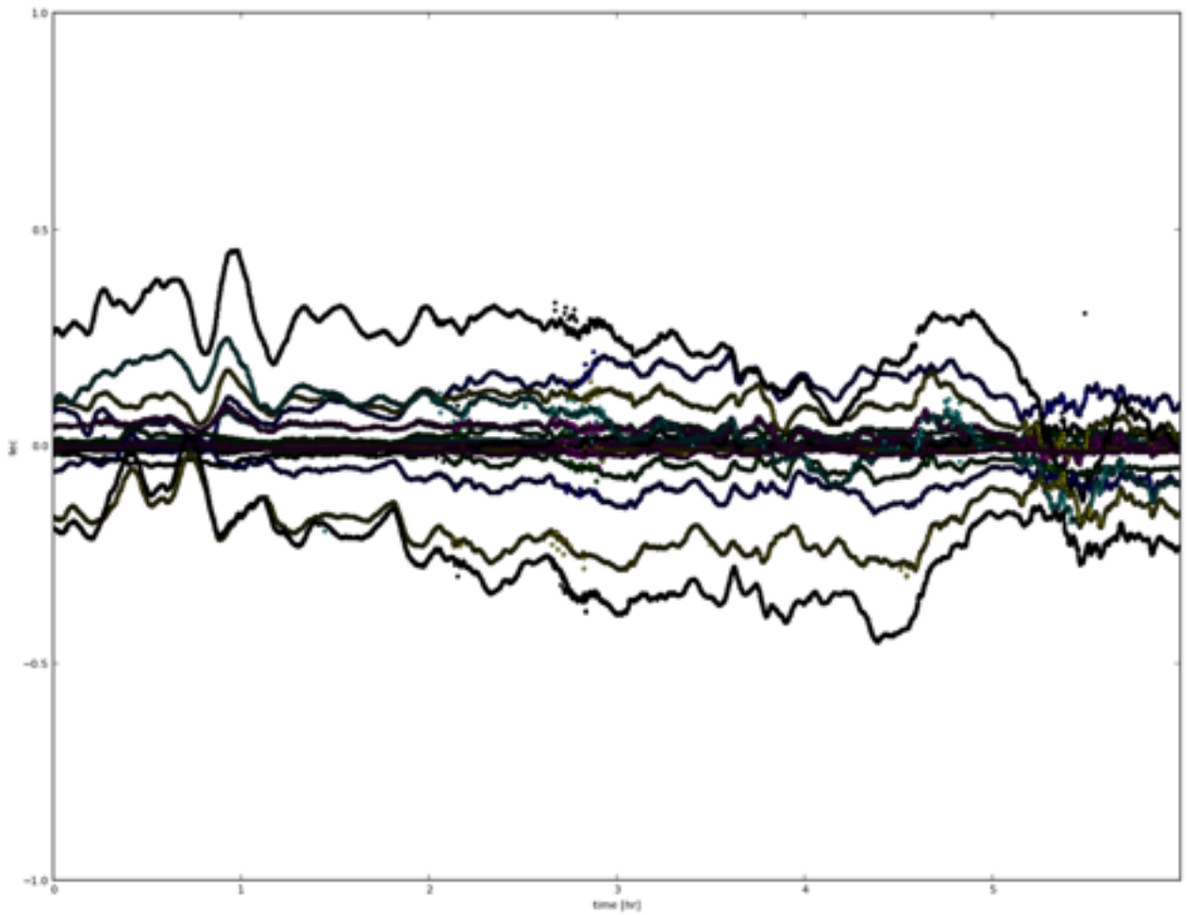
~~TEC~~



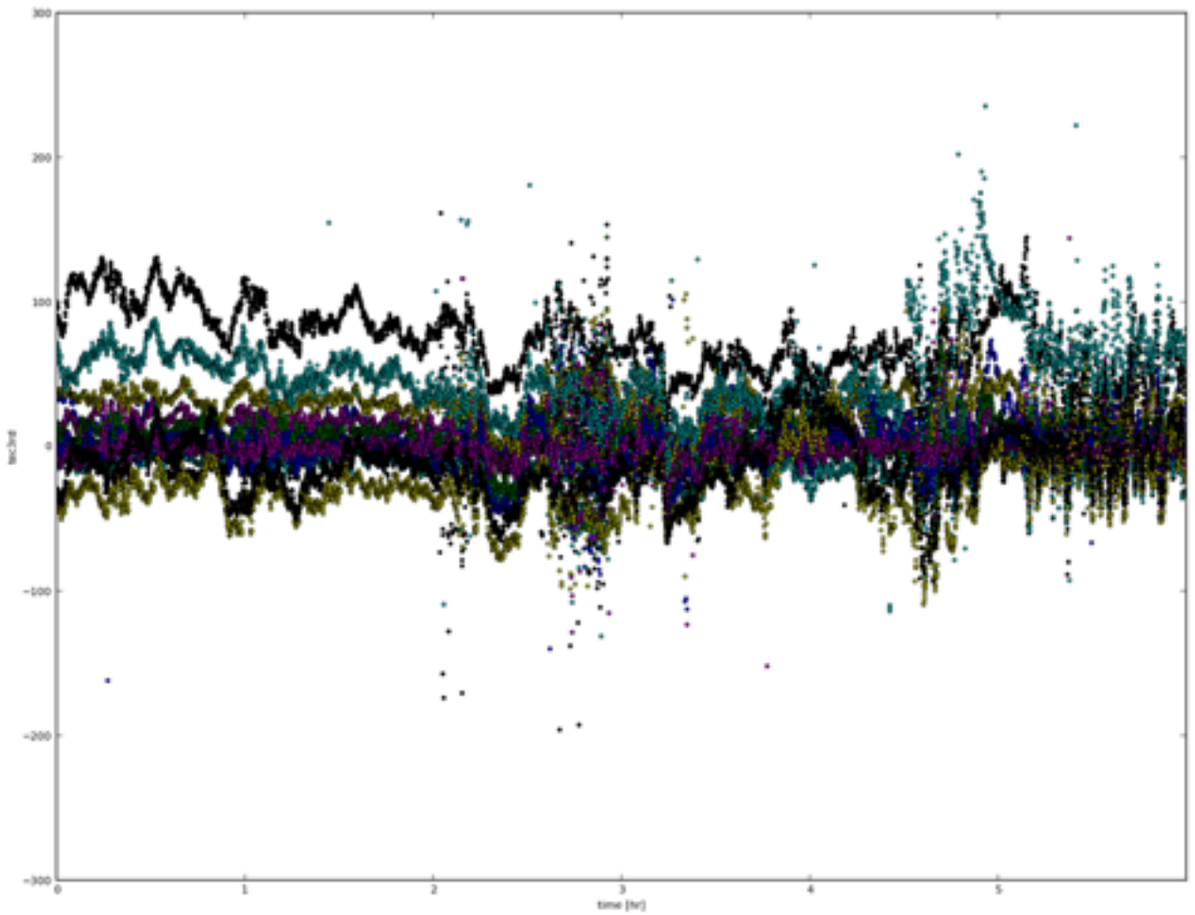


Higher order terms

$$\iota \approx \frac{\kappa}{c\nu^2}\int_0^d n_{\mathrm{e}}(x)\ \mathrm{d}x. + \frac{3\kappa^2}{2c\nu^4}\int_0^d n_{\mathrm{e}}^2(x)\ \mathrm{d}x. + \frac{5\kappa^3}{2c\nu^6}\int_0^d n_{\mathrm{e}}^3(x)\ \mathrm{d}x. + \cdots.$$



TEC (1/f)



EC2 (1/f^3)

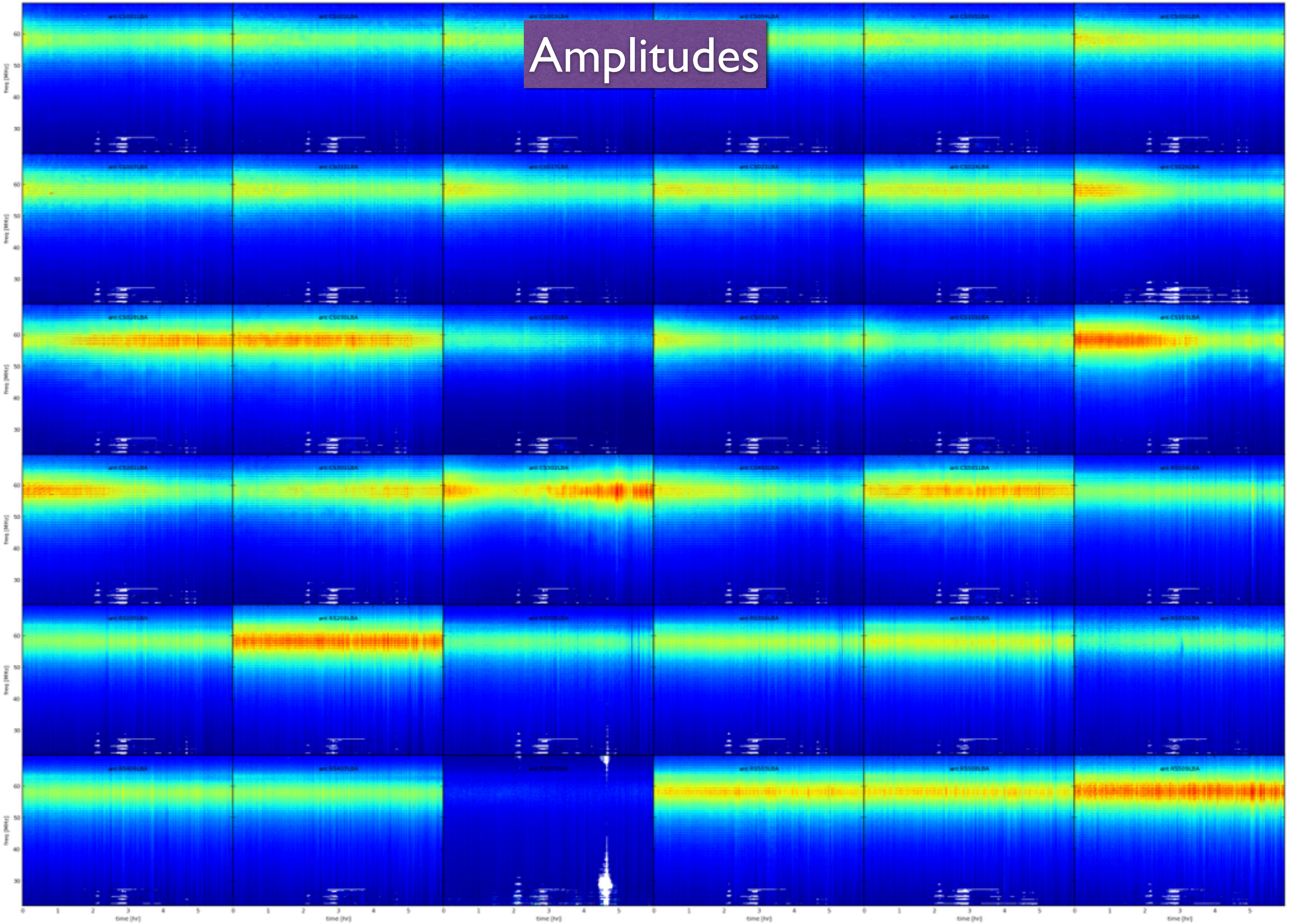
Phases residuals RR

LOFAR phases can be described with just Clock, TEC, FR

Scintillations

	Clock drift	Ionospheric delay	Faraday rotation	Scintillations
Affects	Phase	Phase	Phase (circ) Amp+Ph (lin)	Amplitudes
Type	Scalar	Scalar	Diag (circ) Rot (lin)	Scalar?
Freq. dep.	$\propto f$	$\propto 1/f$; $\propto 1/f^3$	$\propto 1/f^2$	some
Dir. dep.	No	Yes (tens arcmin)	Yes (degrees)	Yes (tens arcmin)

Amplitudes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ant:CS006LBA
ant:CS007LBA
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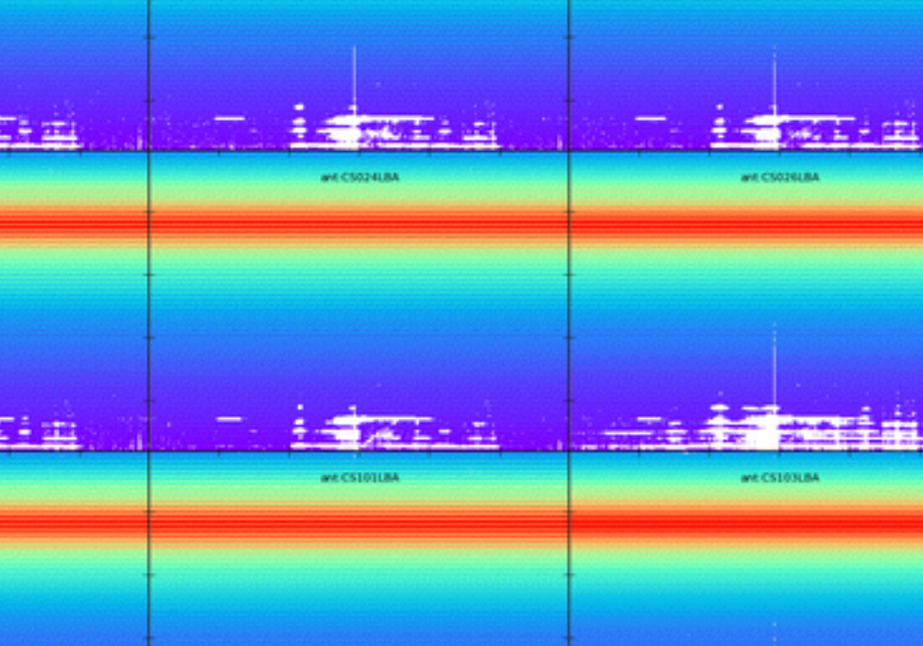
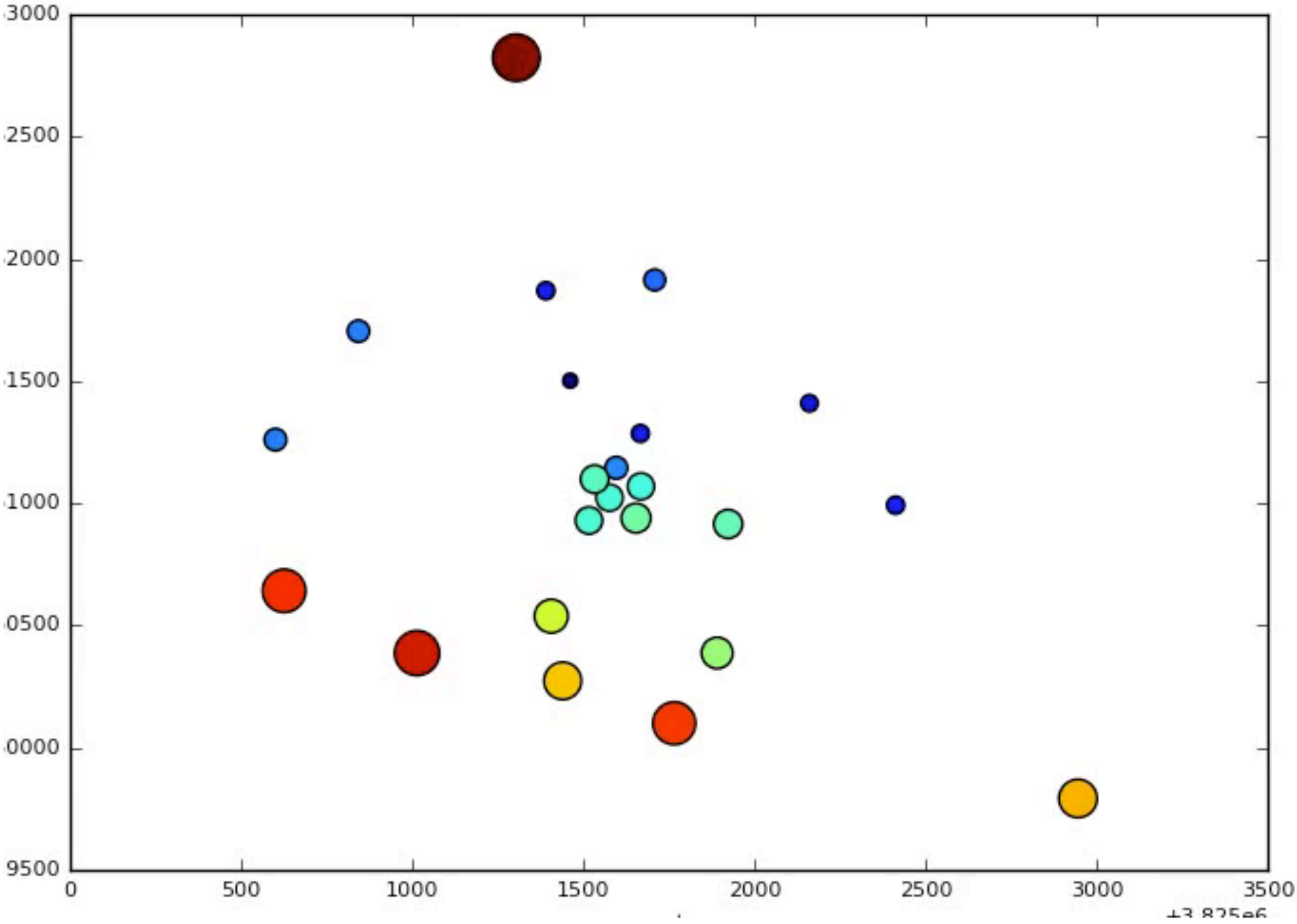
ant:CS028LBA
ant:CS030LBA
ant:CS031LBA
ant:CS032LBA
ant:CS101LBA
ant:CS103LBA
ant:CS201LBA
ant:CS301LBA
ant:CS302LBA
ant:CS401LBA
ant:CS501LBA
ant:RS106LBA
ant:RS205LBA
ant:RS208LBA
ant:RS305LBA
ant:RS306LBA
ant:RS307LBA
ant:RS310LBA
ant:RS406LBA
ant:RS407LBA
ant:RS409LBA
ant:RS503LBA
ant:RS508LBA
ant:RS509LBA
freq [MHz]
time [hr]

Amplitudes


Normalized amplitude
Frequency [MHz]
0
0.2
0.4
0.6
0.8
1
0
10
20
30
40
50
60
70
80
90

Amplitudes residuals


3000
2500
2000
1500
1000
0500
0000
9500
0
500
1000
1500
2000
2500
3000
3500

Ionospheric effects <100 MHz

	Clock drift	Ionospheric delay	Faraday rotation	Scintillations
Affects	Phase	Phase	Phase (circ) Amp+Ph (lin)	Amplitudes
Type	Scalar	Scalar	Diag (circ) Rot (lin)	Scalar?
Freq. dep.	$\propto f$	$\propto 1/f$; $\propto 1/f^3$	$\propto 1/f^2$	some
Dir. dep.	No	Yes (tens arcmin)	Yes (degrees)	Yes (tens arcmin)