PAON4 : Array geometry from satellites

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- What is the needed precision on the array geometry, pointing, phases … in order to combine the signals from different pairs et and not degrade the cosmological signals

- For PAON4 , we have seen that the imperfect knowledge of these parameters prevents us from combining the visibilities to make maps around the bright sources

- We try to understand the phase correction terms for PAON4 visibilities beyond phases reconstructed on CasA transit.

- Use of satellite tracks (Galileo, GPS, Beidou …) to reconstruct both individual antennae pointing directions, as well as phase differences

- A long duration continous observation run (**LD14Jan19**) was carried in January 2019 (14-23 Jan), and 4 directions : CasA (z=+11.4 deg), CygA (z=-6.5 deg), M1/Crab (z=-25 deg) and M87/VirgoA (z=-35 deg)

- Analysis work is still under development (mi-march) - but very encouraging results

- ① Use auto-correlations signals from satellites in the first step, to determine the individual antenna pointing direction, and effective dish size (a beam model is required) - Determination of two angles (Elev, Azimuth) and D_dish for each of the 4 antennae - Determines also the source amplitude and signal offset (Tsys) for each source. The determination of the pointing and beam model is done on each fixed declination observation independently (4 set of observations for LD14Jan19)

- ② In the second step, for each set of fixed declination observation, the pointing and dish size are fixed (determined from AutoCorrelation fit), and for each cross-correlation visibility (6 in the PAON4 case), we determine the phase (and cross-correlation amplitudes) - We use a linear model for frequency dependent phase. We use both the satellite tracks and visibilities from the sky sources in this step.

- Although we do perform the fit independently for each baseline, our checks show that the determined linear phase model are fully compatible between the 6 baselines (3 x 2 independent parameters , instead of the 6 x 2)

- ③In the last step, we try to fit all the cross-correlations from the four directions simultaneously, with a single phase correction model (3 x 2 independent parameters) - It is also possible to leave the array geometry free

$$\Phi(\nu) = \Phi_0 + a_\Phi \times (\nu - 1250.)/250.$$

Findings

- The program (c++) uses non linear fit either the one included in the SOPHYA library, or the CERN Minuit minimization package - We do not see currently significant difference in term of fit quality. As expected, the fits are quite sensitive to the model and initial guess for the parameter values

- Olivier is working on a pointing model for the instrument

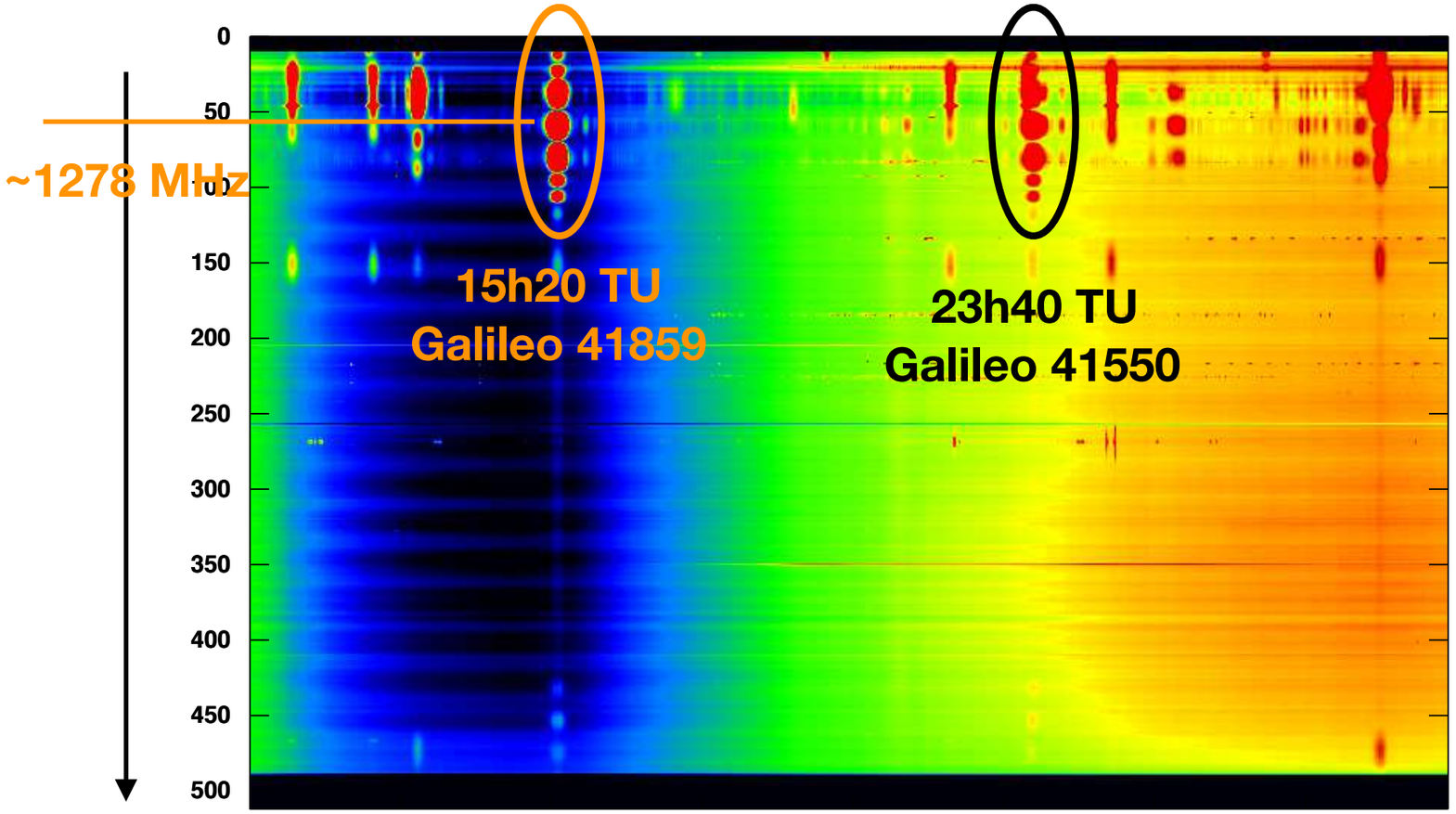
- We do observe a effective dish size changing with declination !

- The compatibility between satellites signals and the ones from the sky source (Cross-Corr) is rather good with the linear frequency dependent phase model

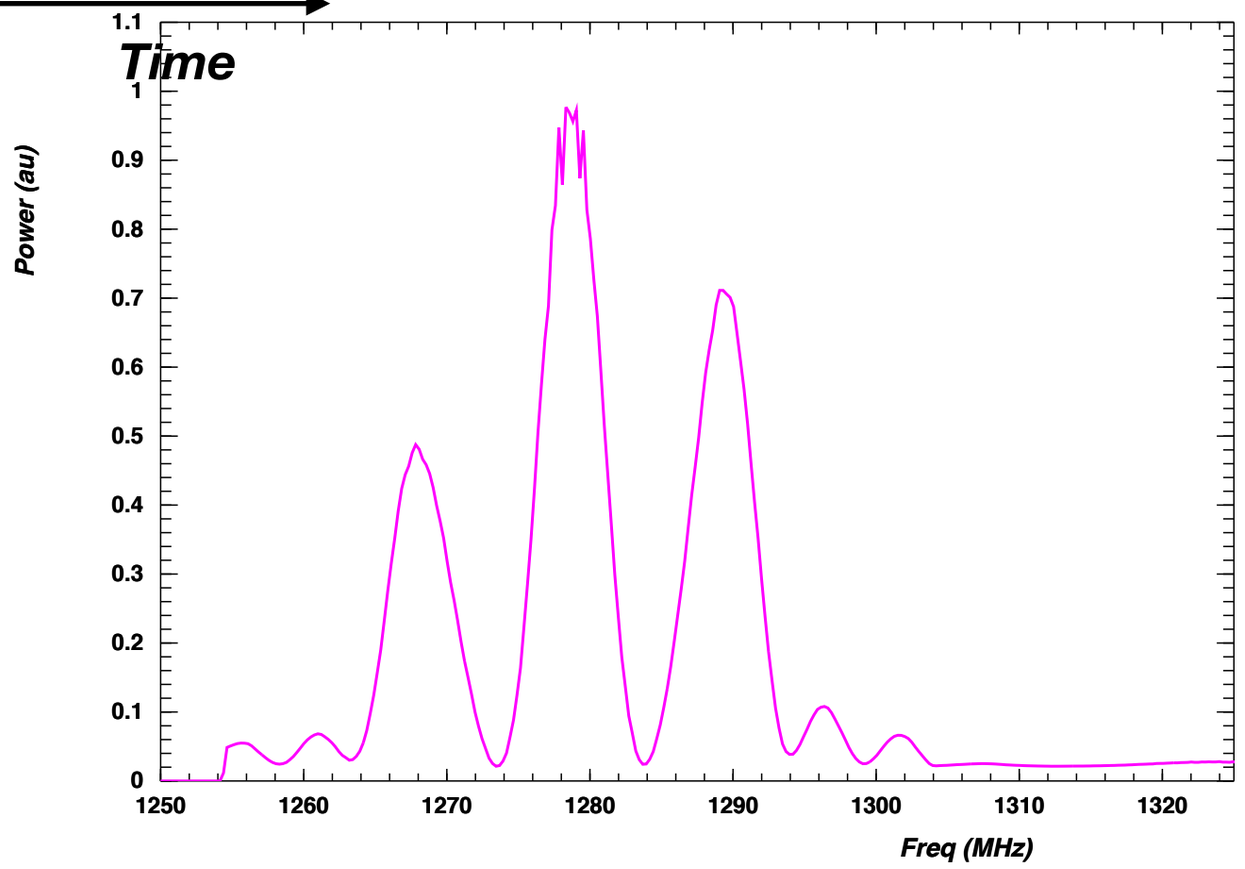
- We observe the phase model parameter changing significantly with observation direction. This is probably due to error in the geometry (antenna ground positions) -

- The global fit where the antenna positions is not yet well constrained enough, specially as the antenna z-coordinates (height) is nearly degenerate with the instrumental phase (delay in cables …)

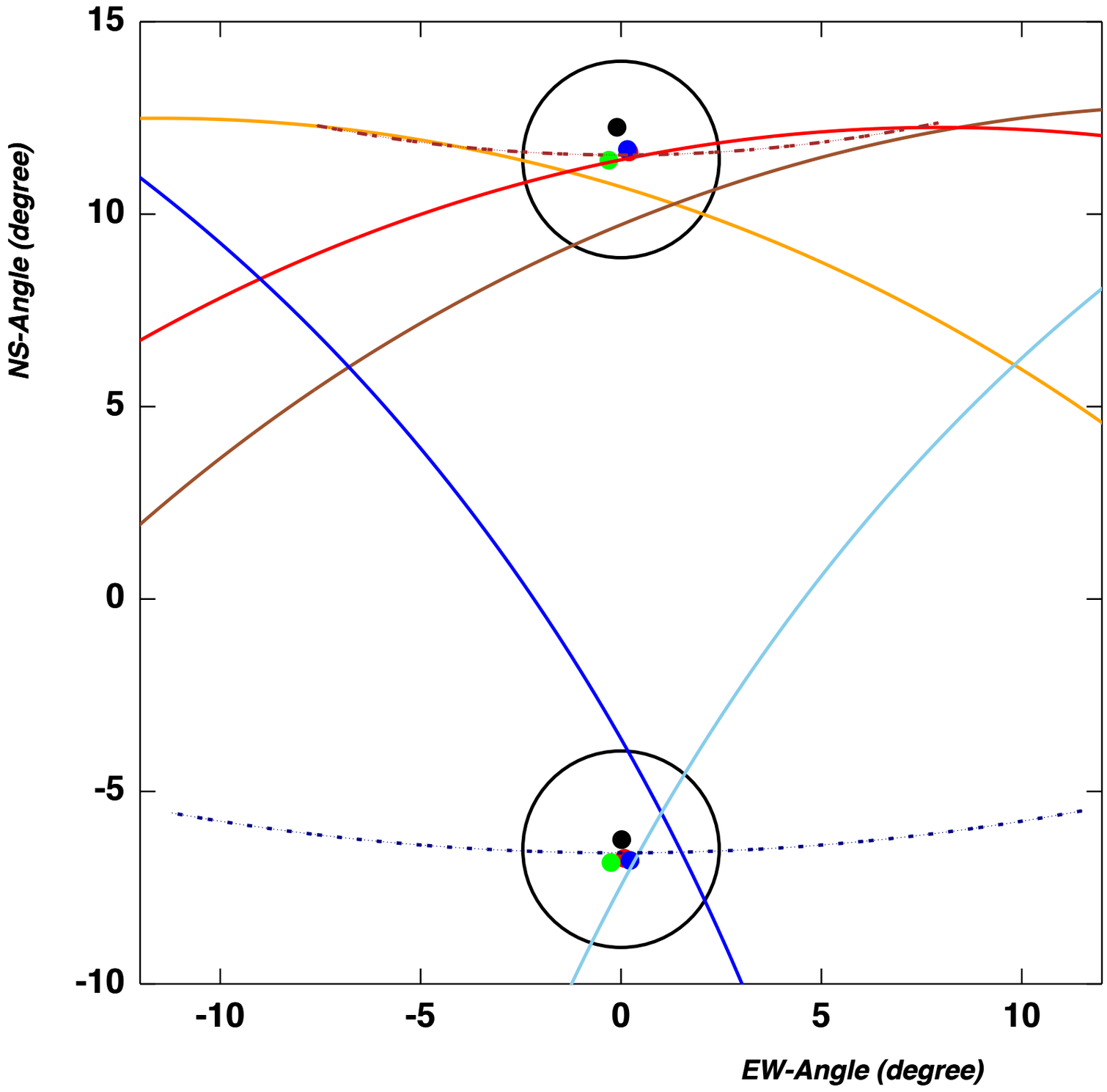
- However, a manual rough scan confirm the z-shift we determined from on site measurements (tilt angles with respect to the horizontal using rods put on the antenna support structures) ~ (-10 cm, +5 cm, -2 cm) for antenna 2,3,4 with respect to antenna 1



TFM_1H , B01 20 Oct.



Galileo satellite tracks and CasA & CygA tracks

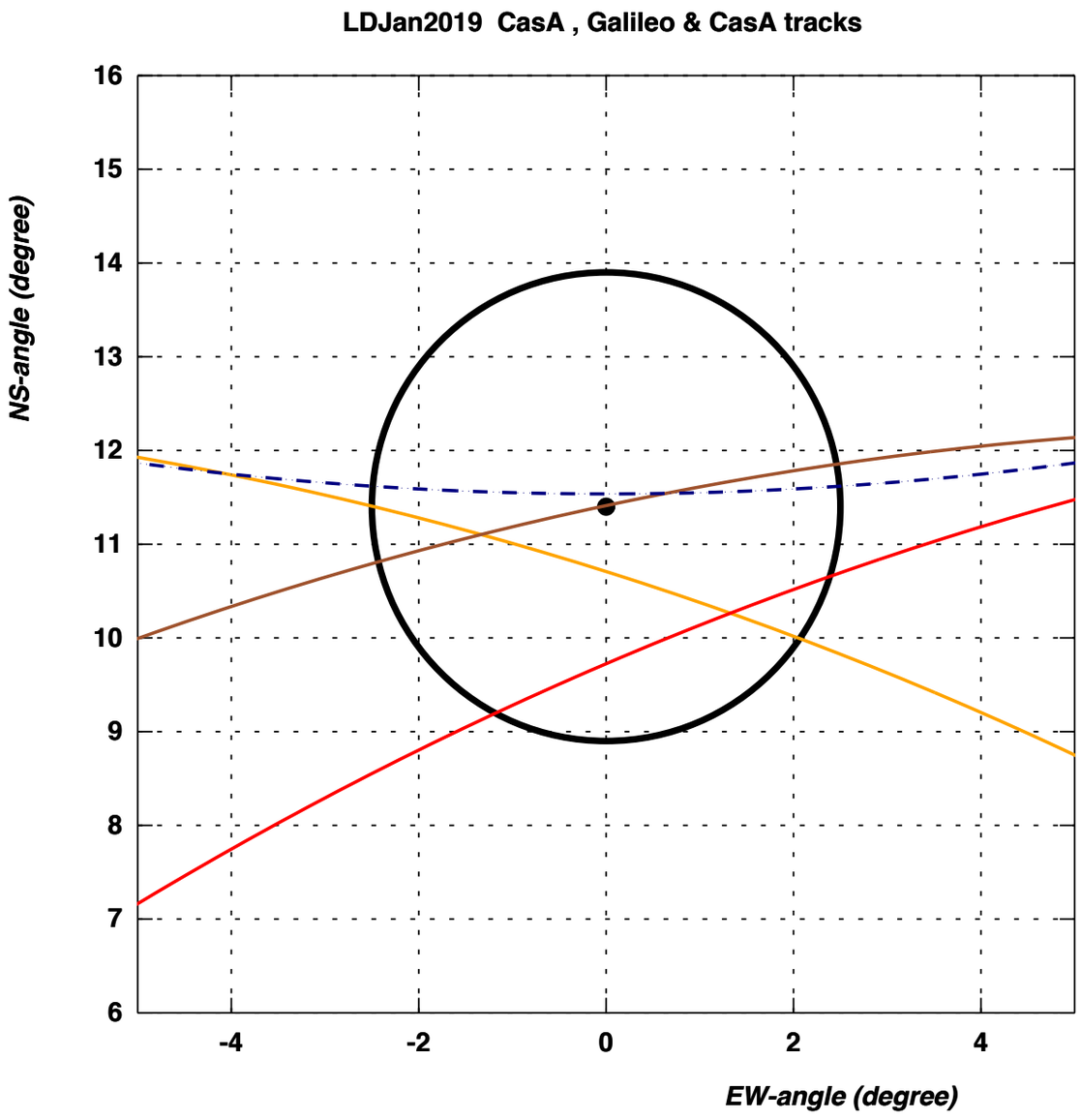


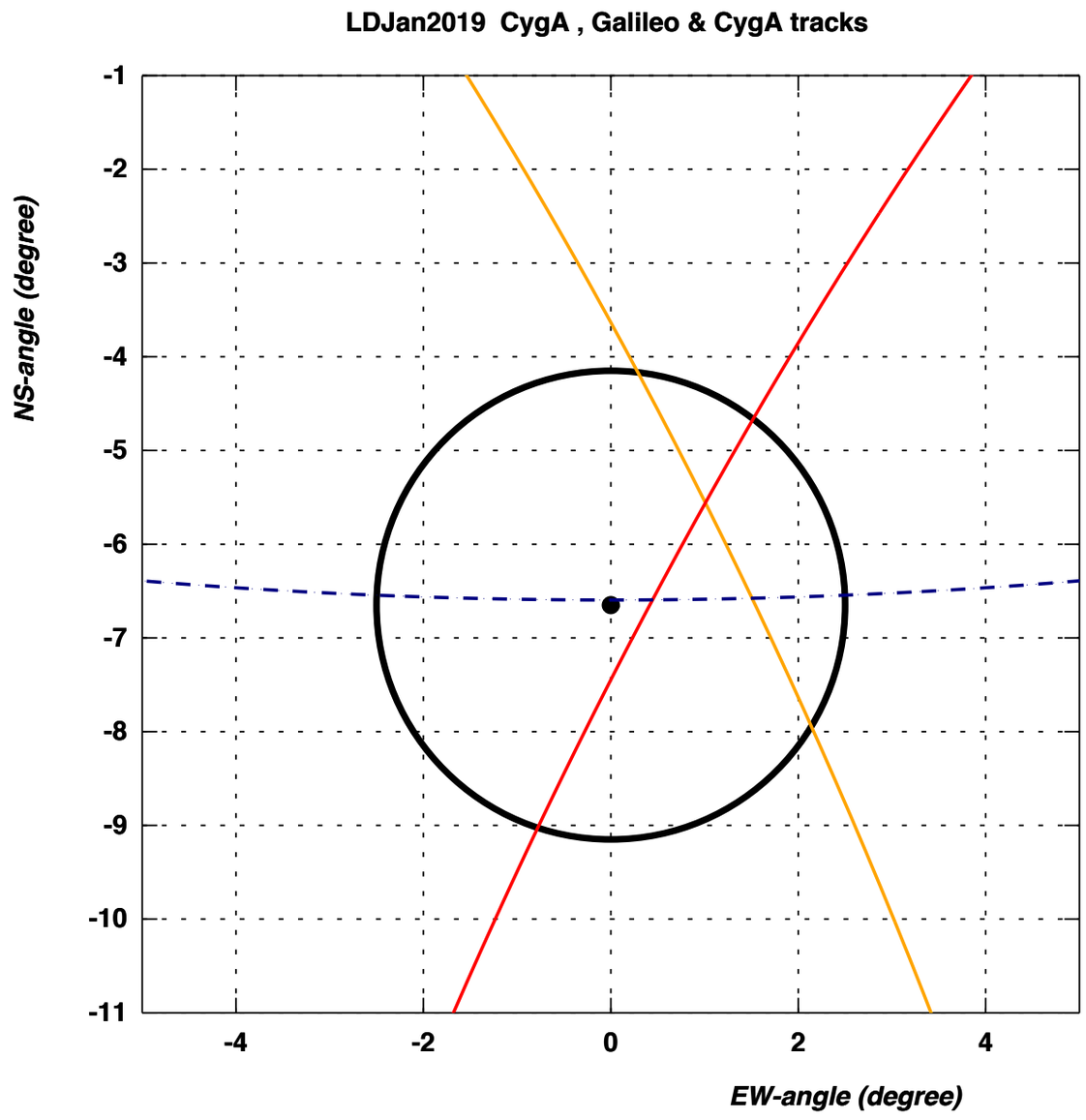
CasA

CygA

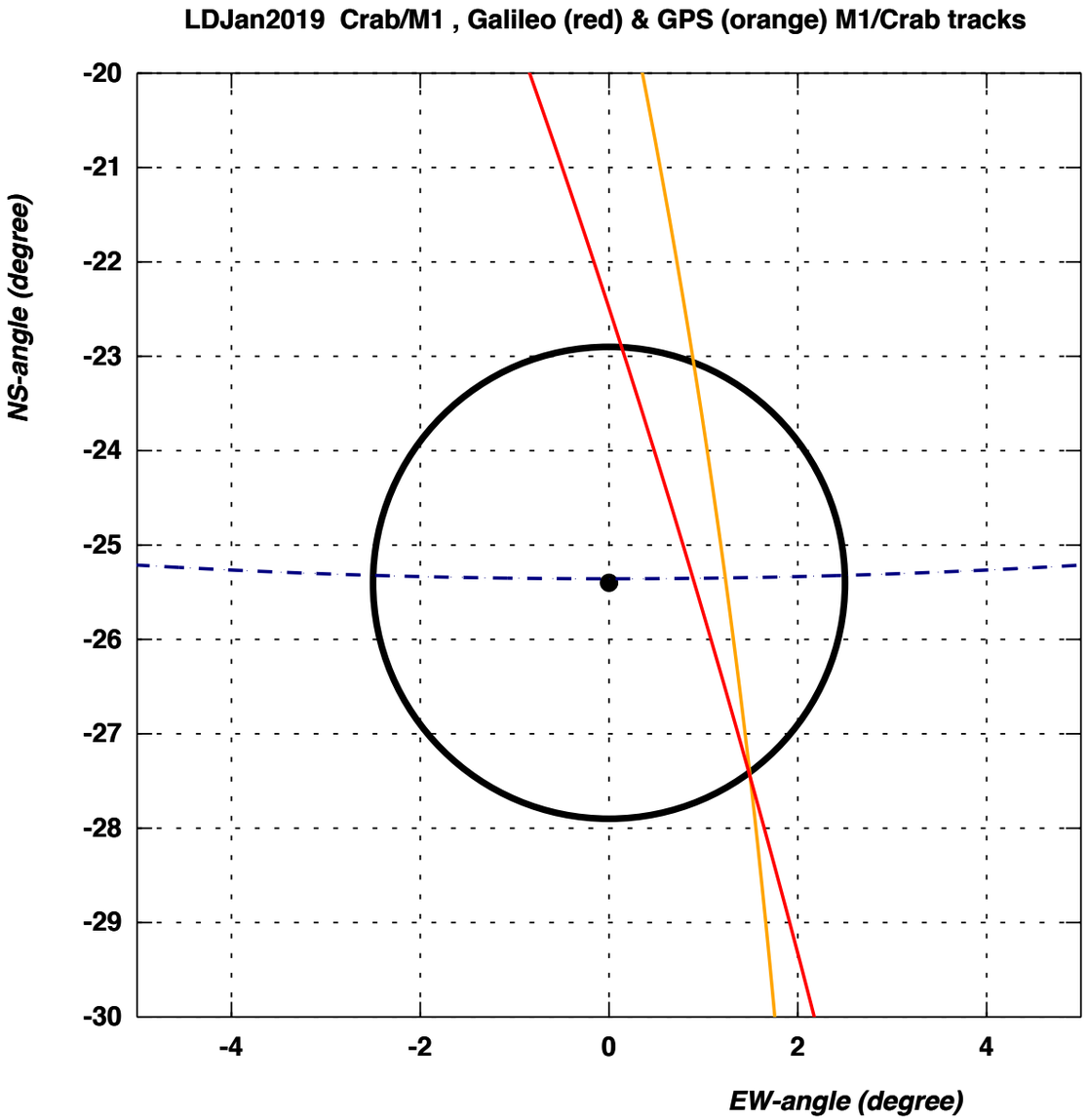
Angular plane

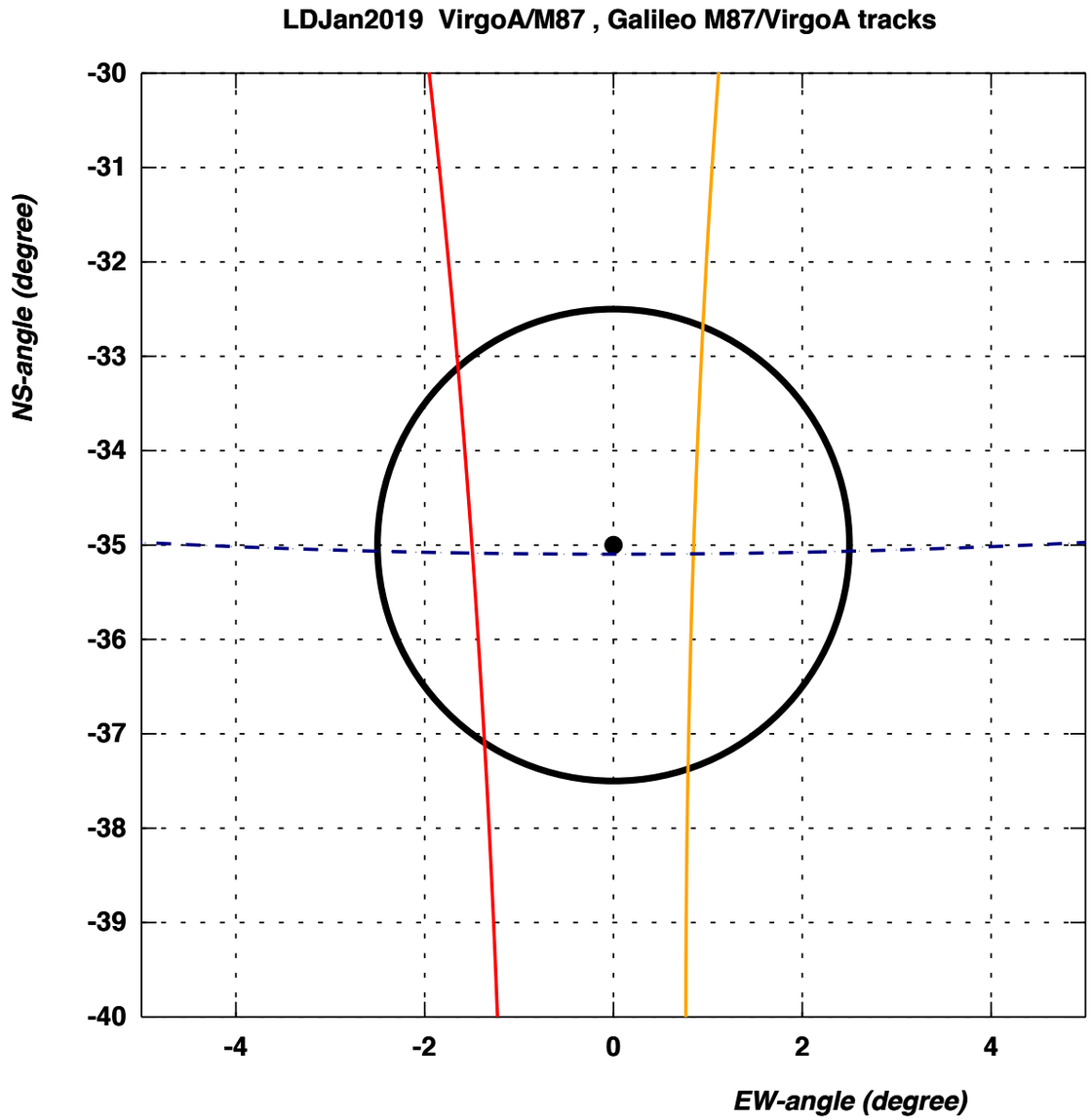
LD14Jan19 : Galileo satellite tracks , observations toward CasA & CygA



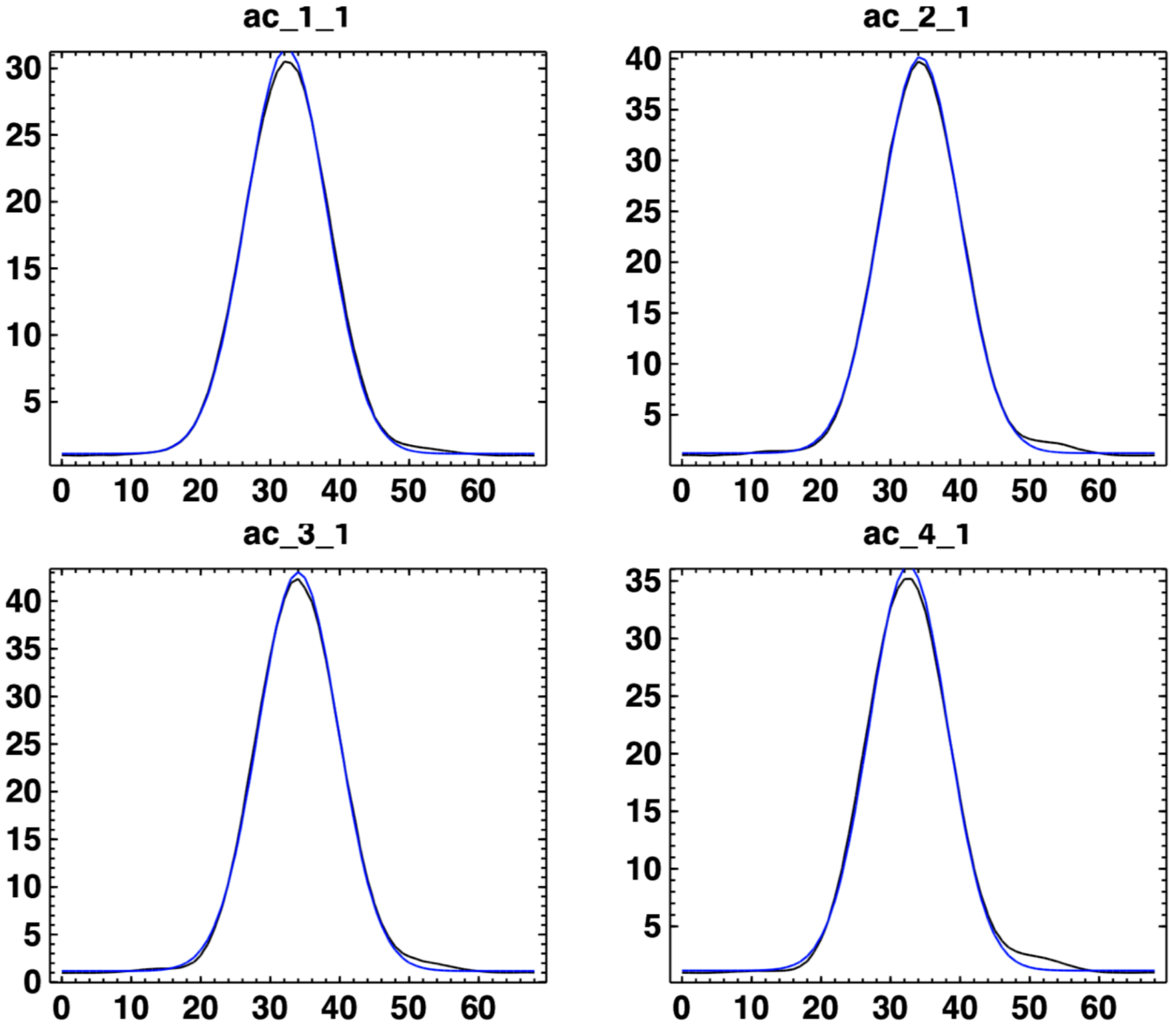


LD14Jan19 : Galileo/GPS satellite tracks , observations toward M1/Crab & M87/VirgoA





PAON4-LDJan2019 , Observing toward CasA (z=-11.4) Galileo satellite track
4 Auto-correlation (H-polar))

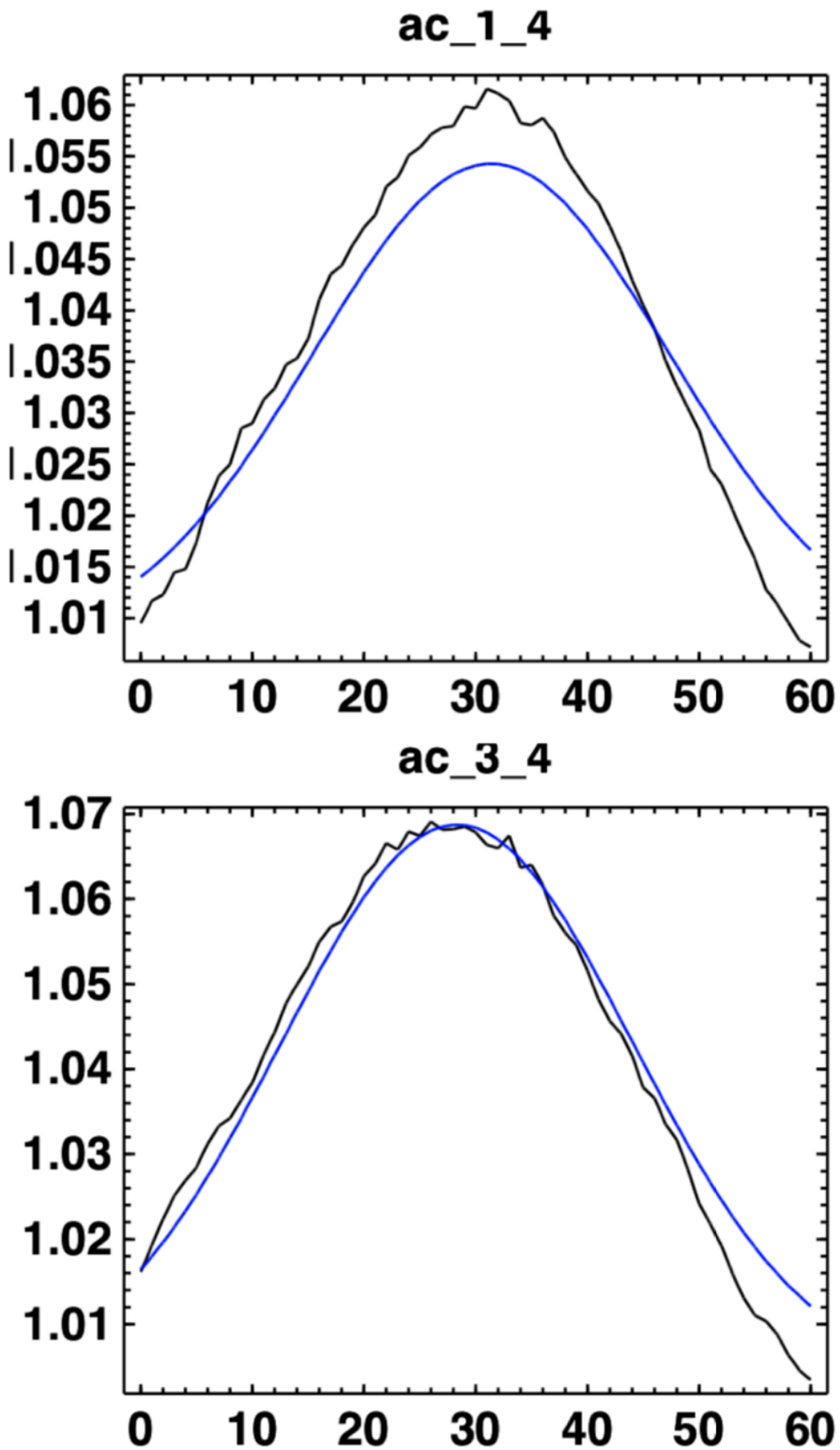


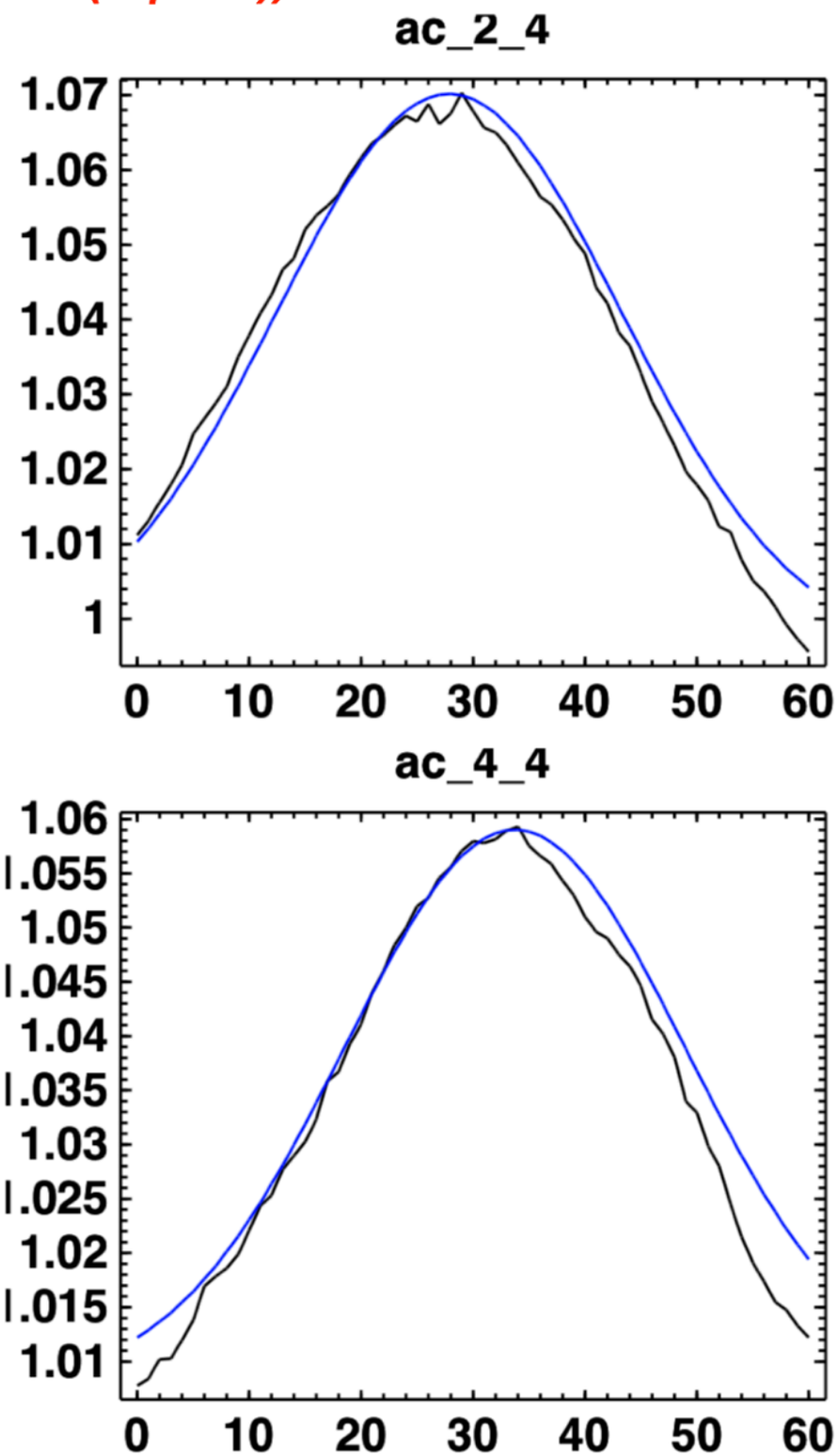
Sat #1

Black : PAON4 signal

Blue : expected (computed) after pointing direction, dish size and amplitude fit

PAON4-LDJan2019 , Observing toward CasA (z=-11.4) CasA track
4 Auto-correlation (H-polar))



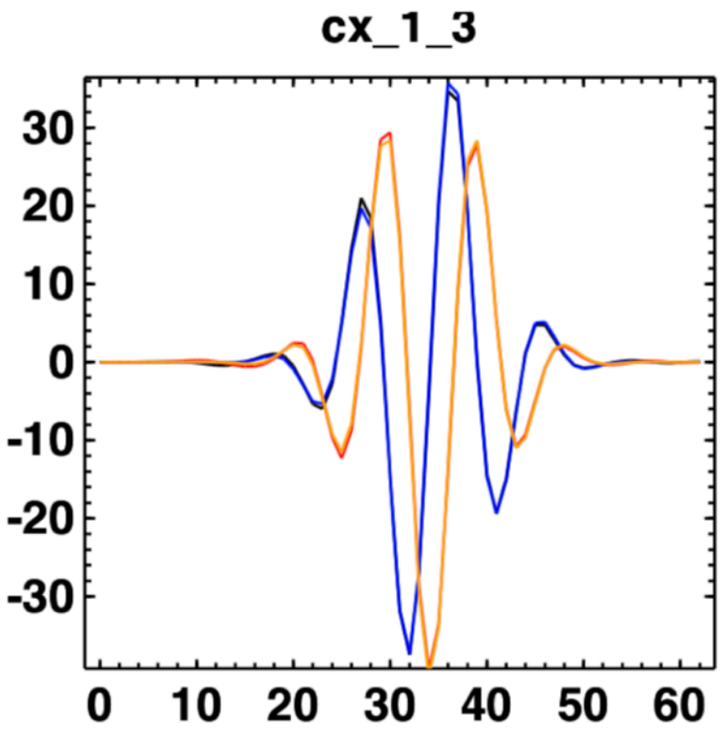


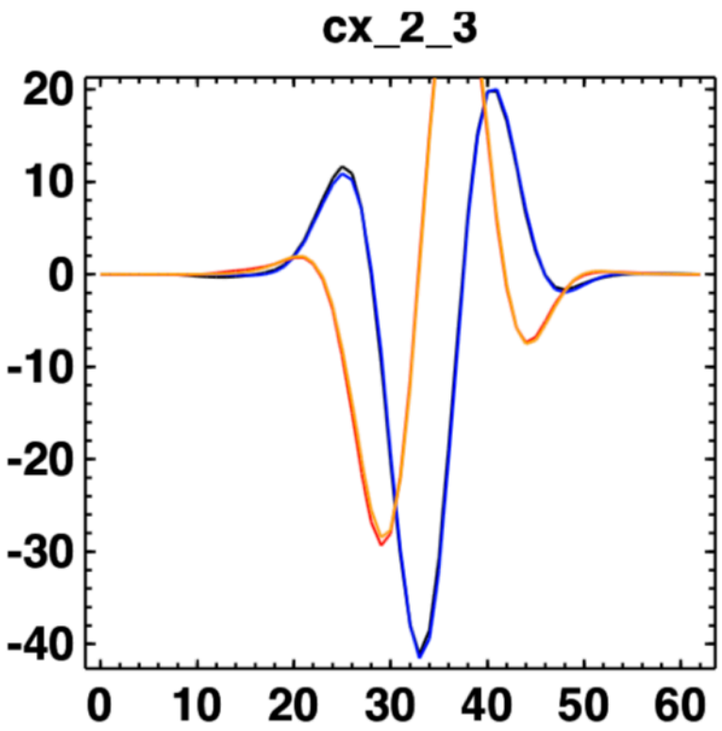
Black : PAON4 signal

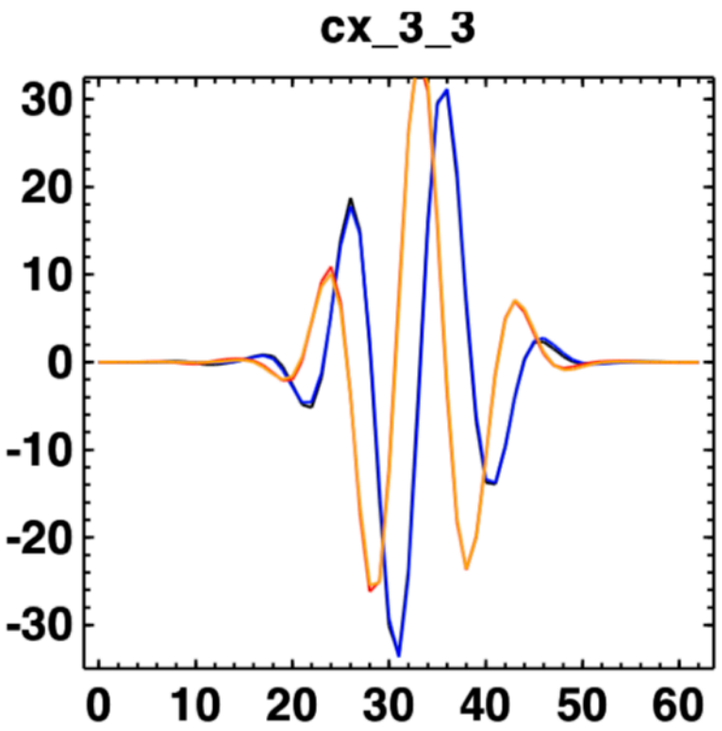
Freq #1 (1346 MHz)

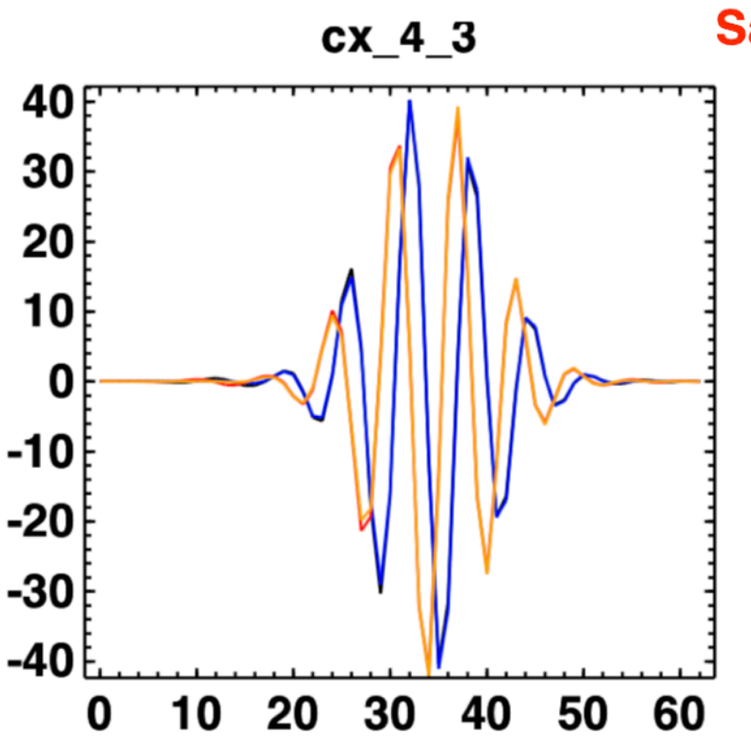
Blue : expected (computed) after pointing direction, dish size and amplitude fit onsatellites

PAON4-LDJan2019 , Observing toward CasA (z=-11.4) Galileo satellite track
6 HH Cross-correlation)

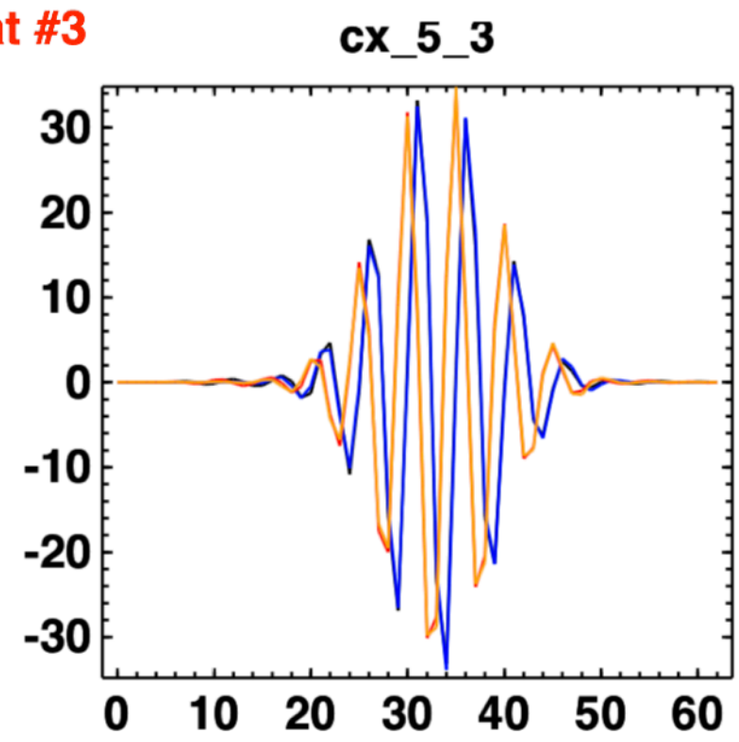


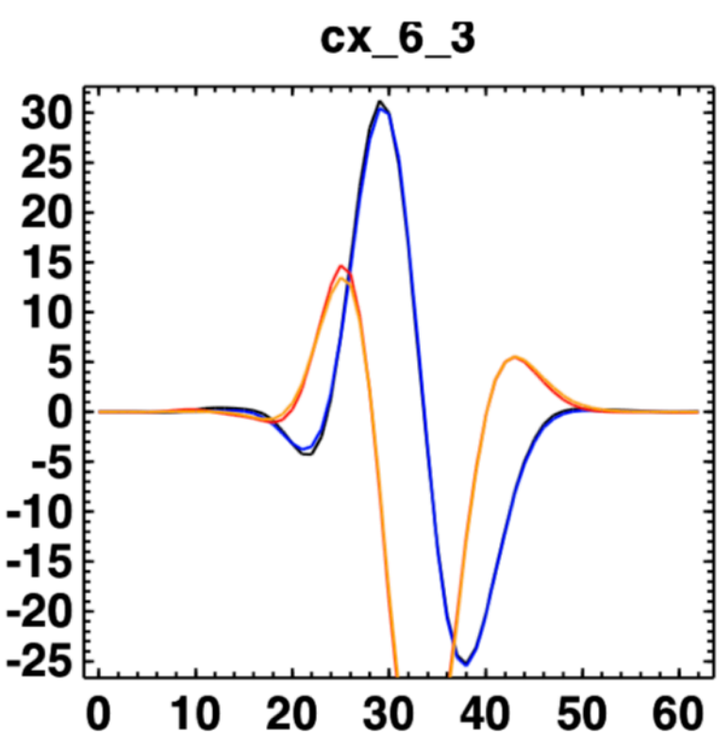






Sat #3





Black : PAON4 signal - Real(visi)

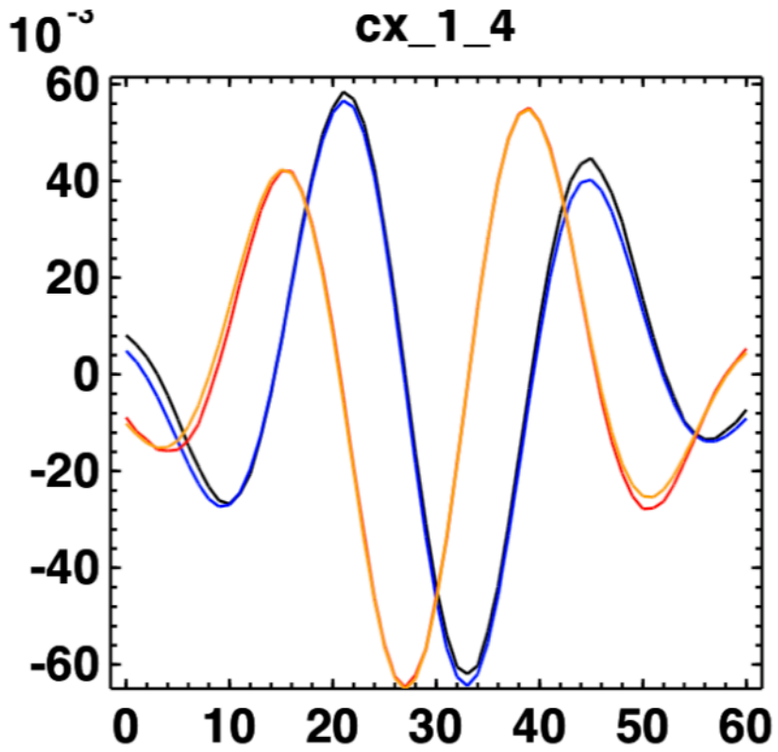
Red : PAON4 signal - Imag(visi)

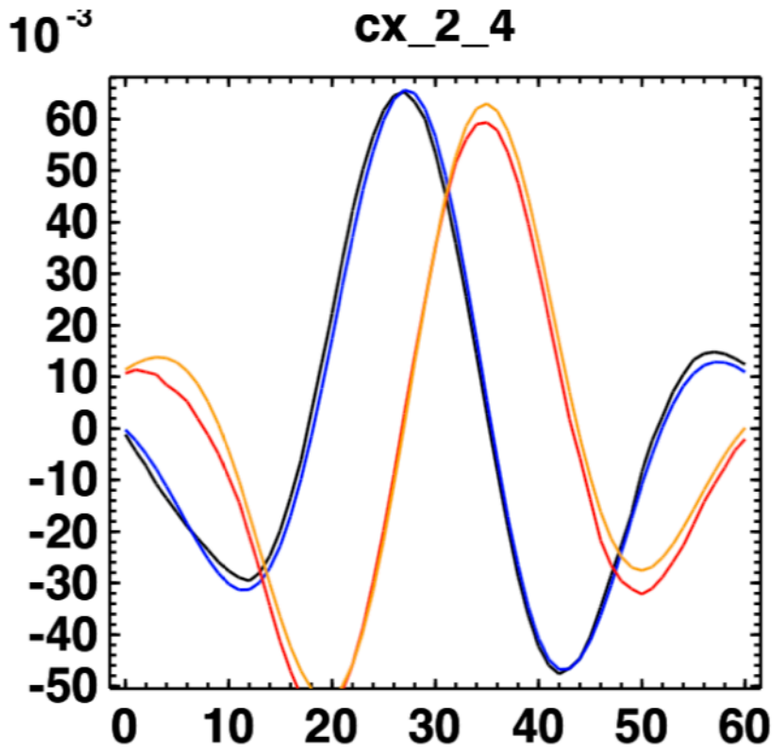
Blue : Expected signal - Real

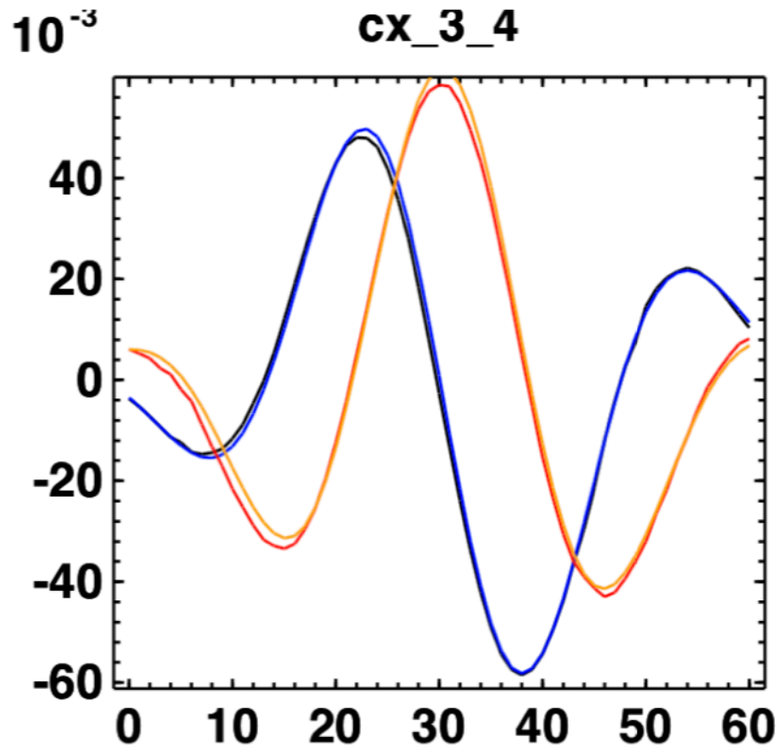
Orange : Expected signal - Imaginary

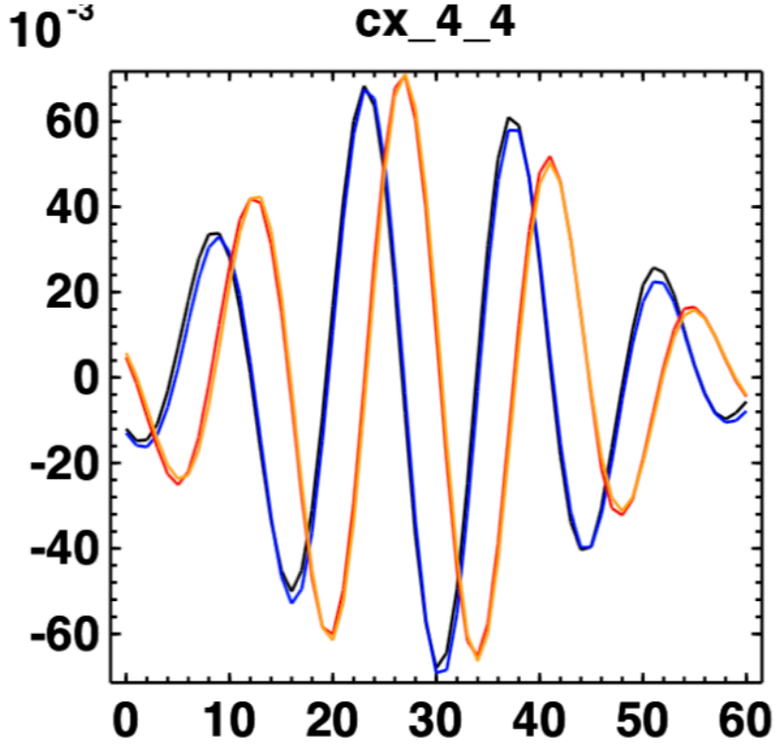
Sat #3

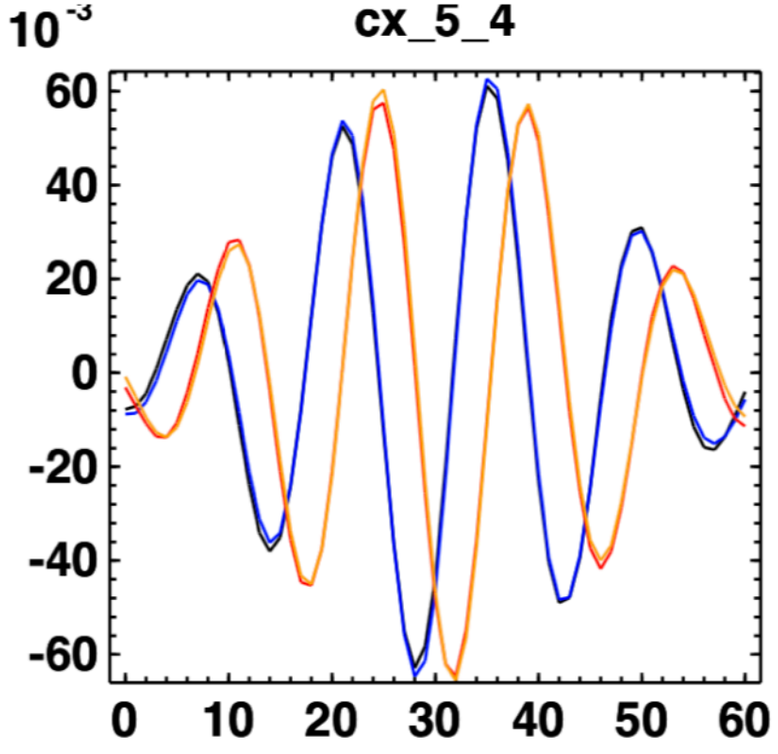
PAON4-LDJan2019 , Observing toward CasA (z=-11.4) CasA track
6 HH Cross-correlation) - frequency f=1346 MHz

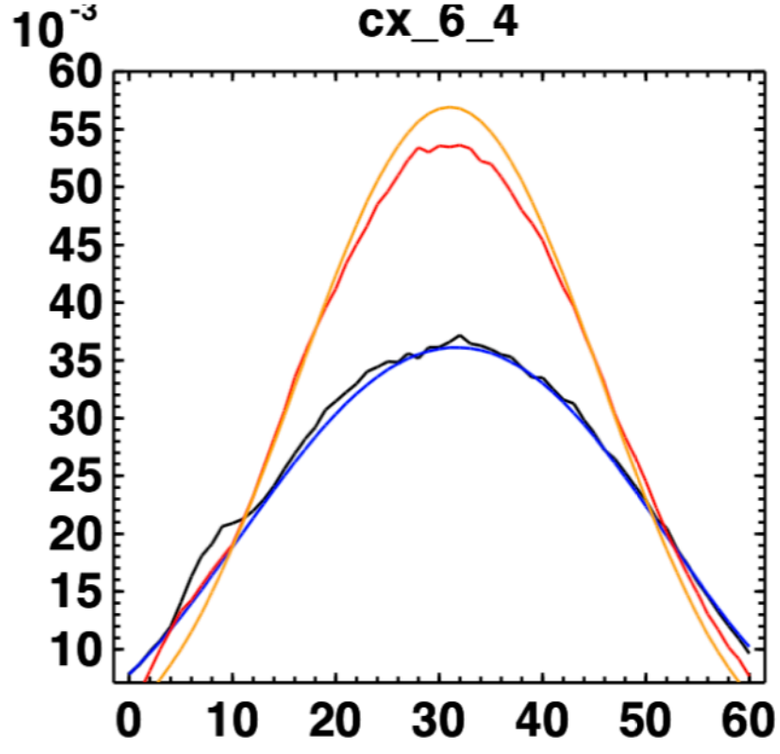












Black : PAON4 signal - Real(visi)

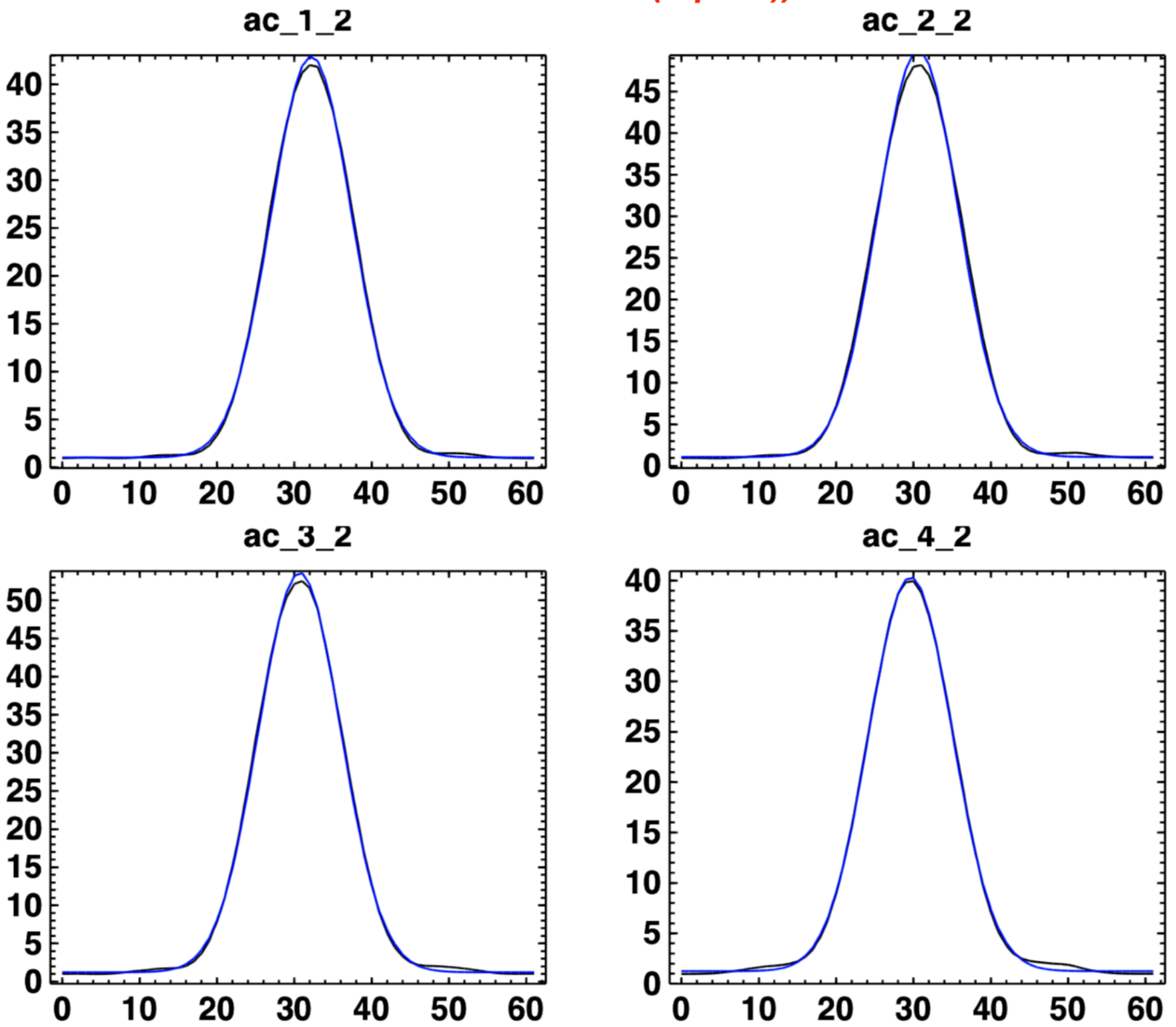
Red : PAON4 signal - Imag(visi)

CasA @ 1346 MHz)
transit 1

Blue : Expected signal - Real

Orange : Expected signal - Imaginary

PAON4-LDJan2019 , Observing toward CygA (z=+6.5) Galileo satellite track
4 Auto-correlation (H-polar))

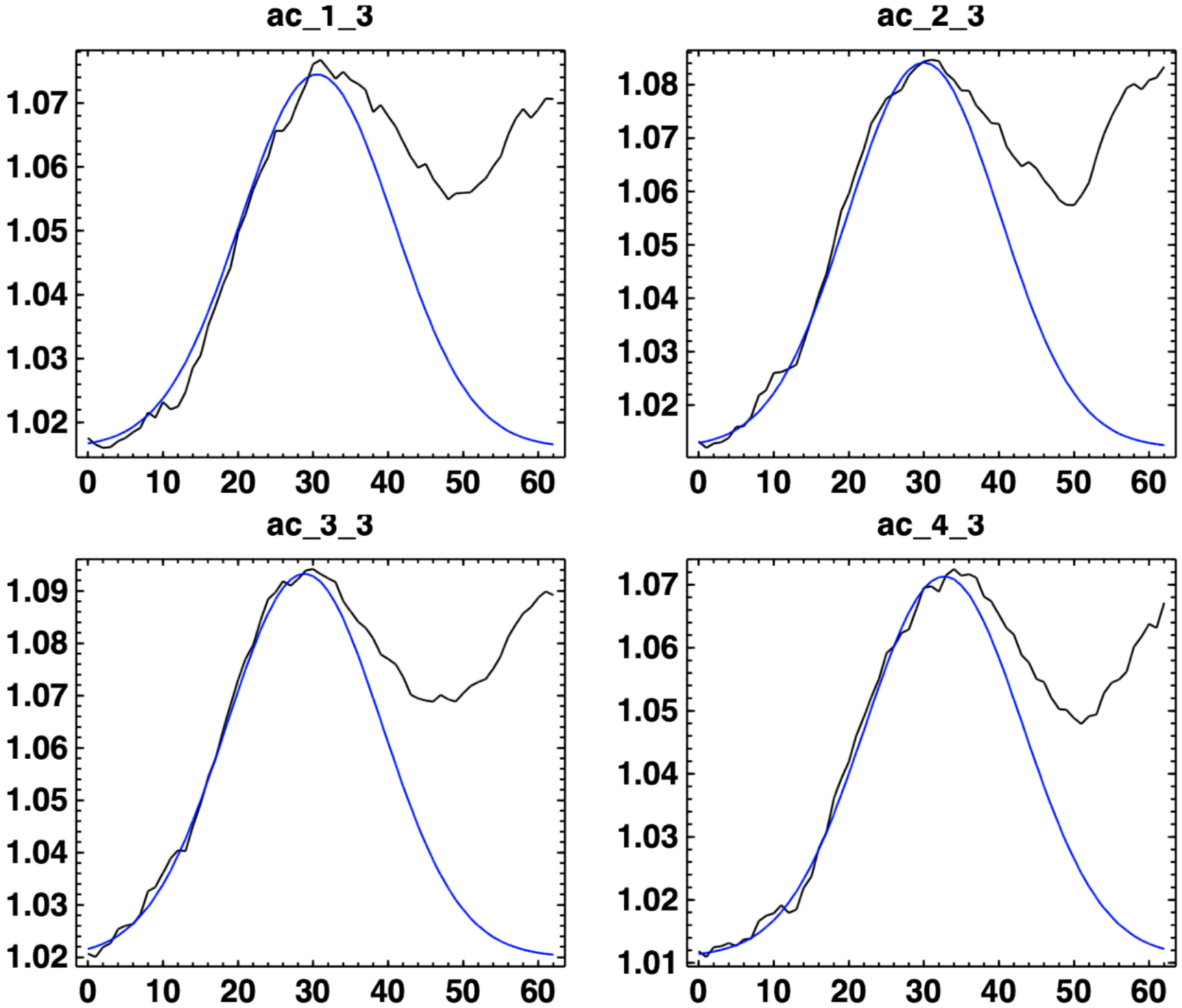


Sat #2

Black : PAON4 signal

Blue : expected (computed) after pointing direction, dish size and amplitude fit

PAON4-LDJan2019 , Observing toward CygA (z=+6.5) CygA track
4 Auto-correlation (H-polar))

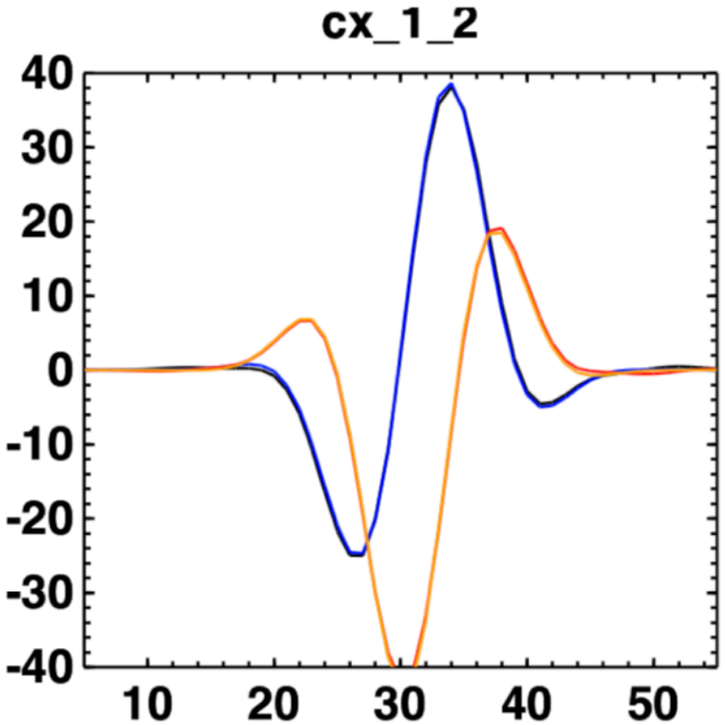


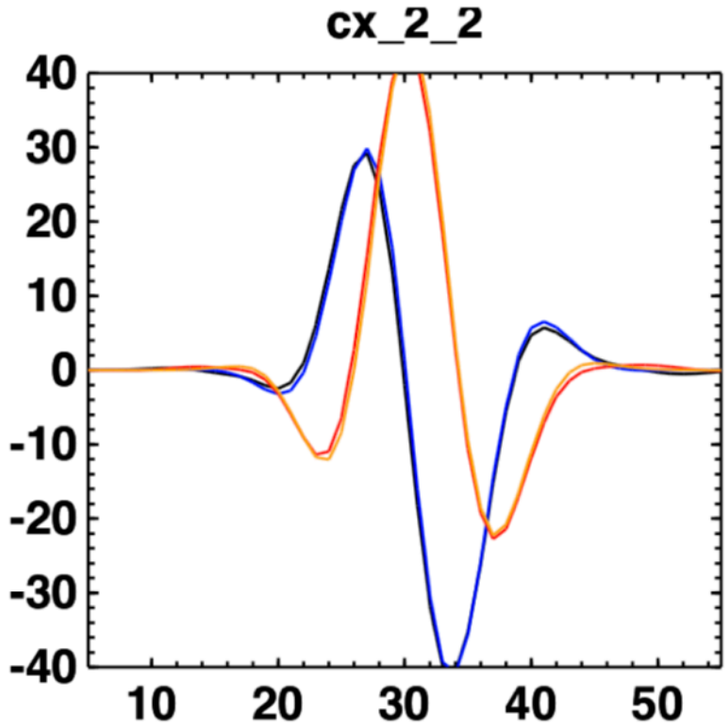
CygA @1346 MHz

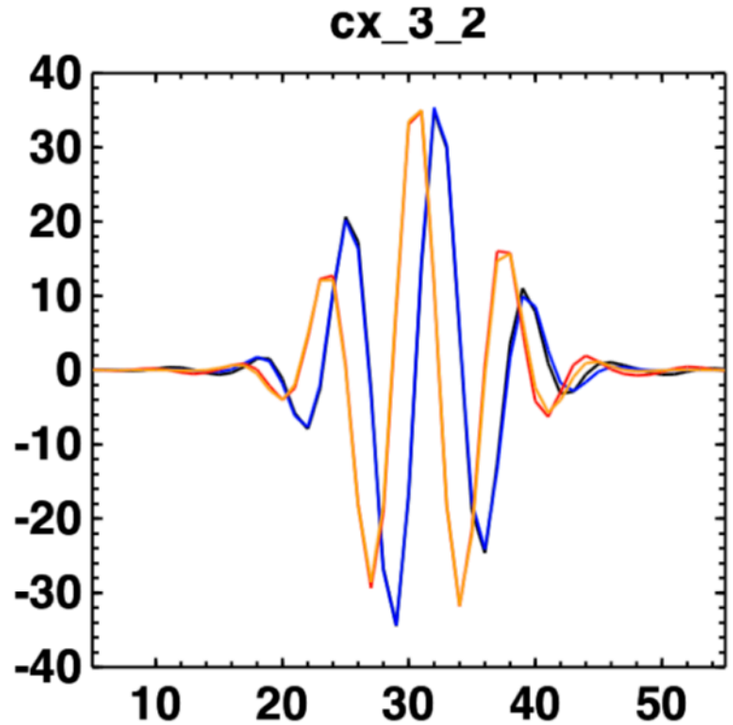
Black : PAON4 signal

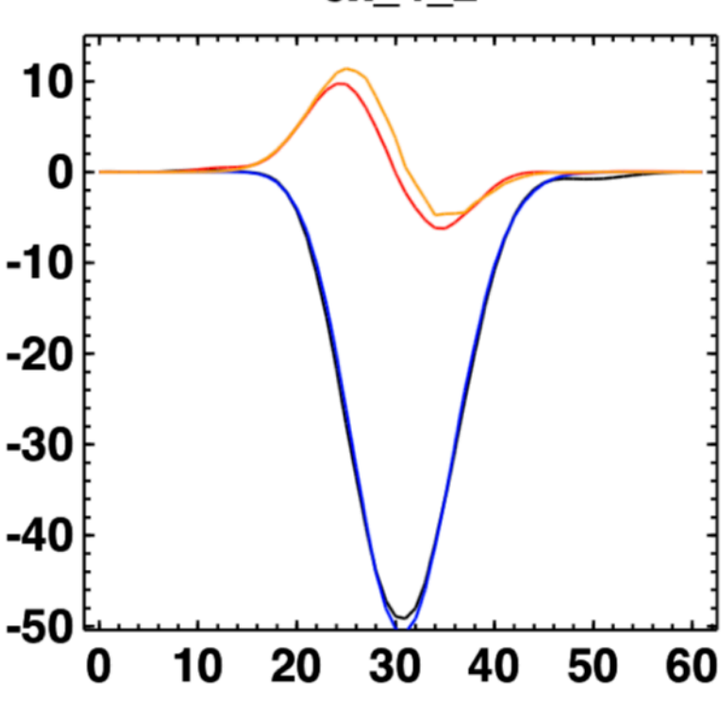
Blue : expected (computed) after pointing direction, dish size and amplitude fit

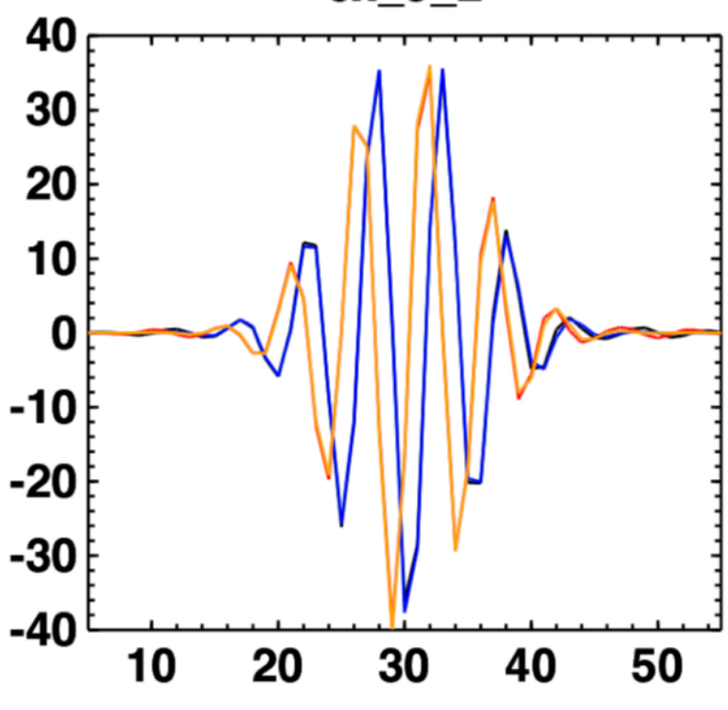
PAON4-LDJan2019 , Observing toward CygA (z=+6.5) Galileo satellite track
6 HH Cross-correlations

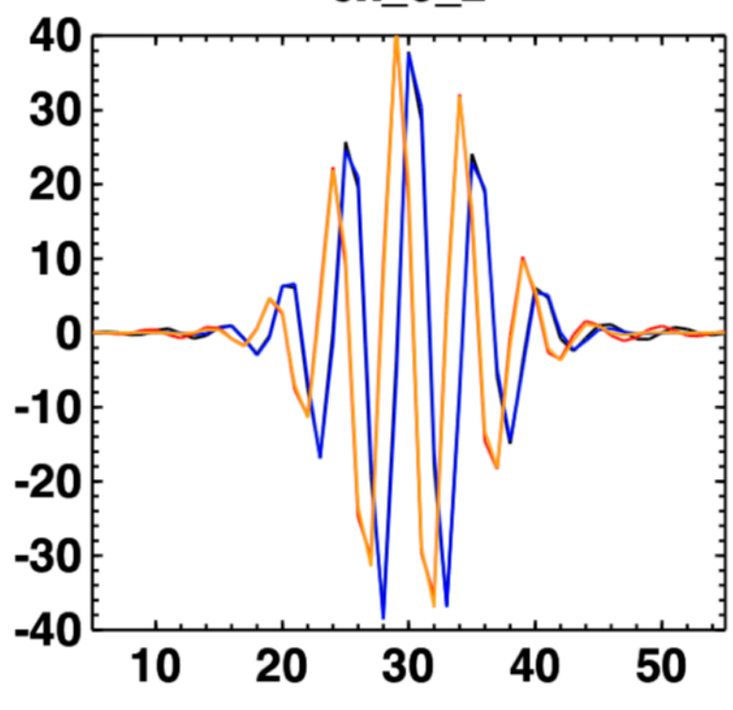












Black : PAON4 signal - Real(visi)

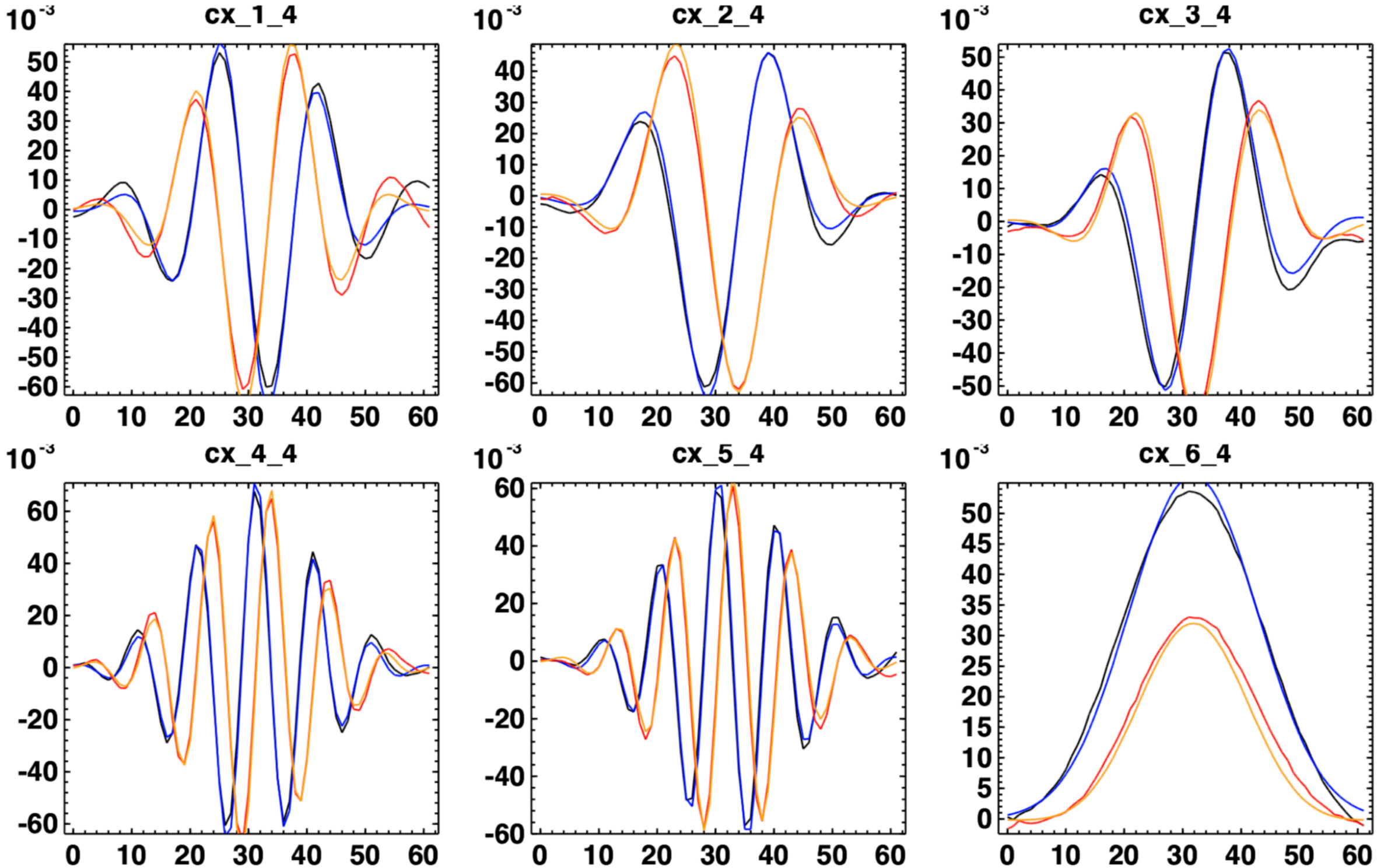
Red : PAON4 signal - Imag(visi)

Blue : Expected signal - Real

Orange : Expected signal - Imaginary

Sat #2

PAON4-LDJan2019 , Observing toward CygA (z=+6.5) Galileo satellite track
6 HH Cross-correlations



Black : PAON4 signal - Real(visi)

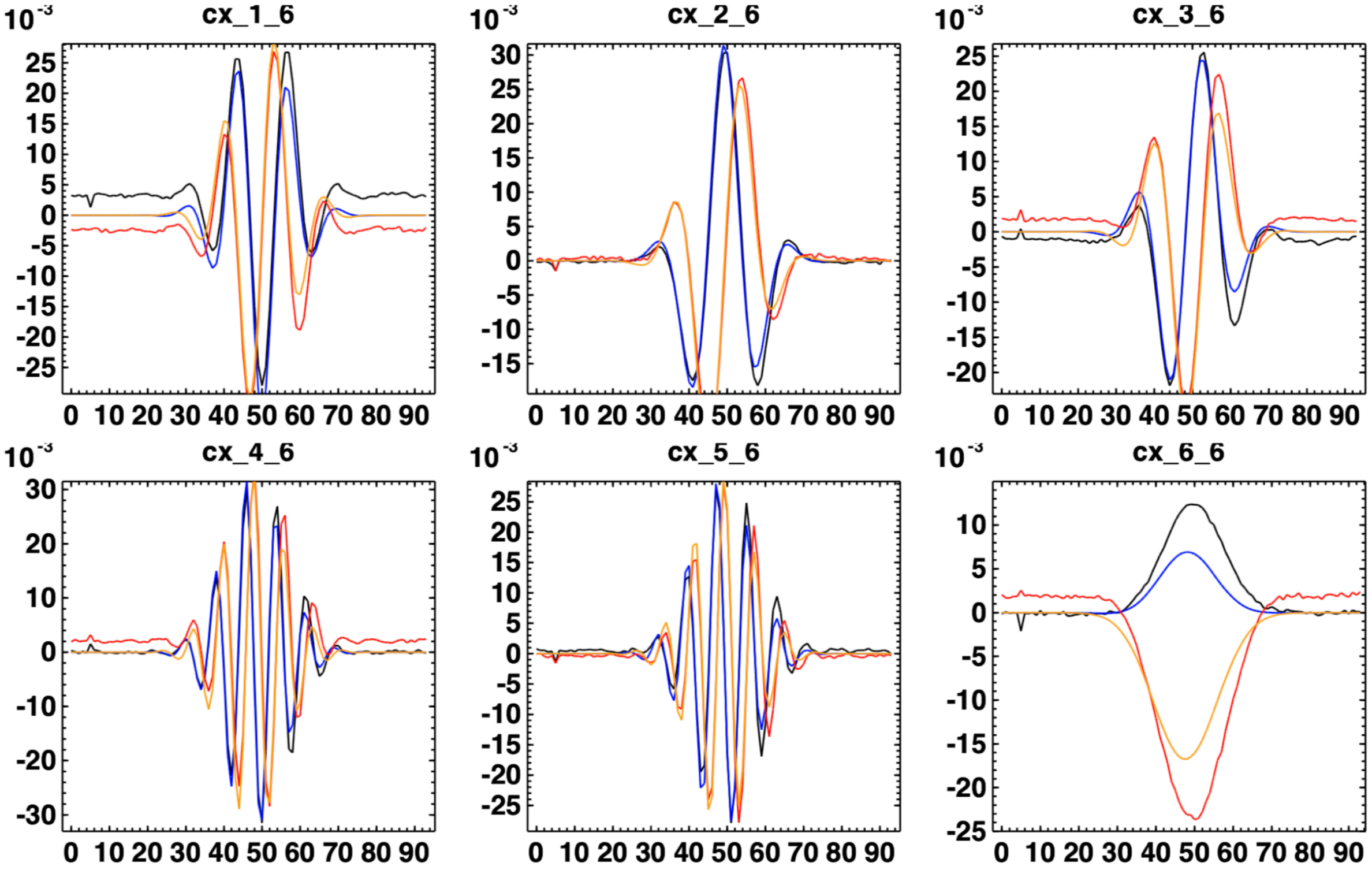
Red : PAON4 signal - Imag(visi)

Blue : Expected signal - Real

Orange : Expected signal - Imaginary

CygA @1396 MHz
Transit #1

PAON4-LDJan2019 , Observing toward Crab (z=+25) Crab track
6 HH Cross-correlations



Black : PAON4 signal - Real(visi)

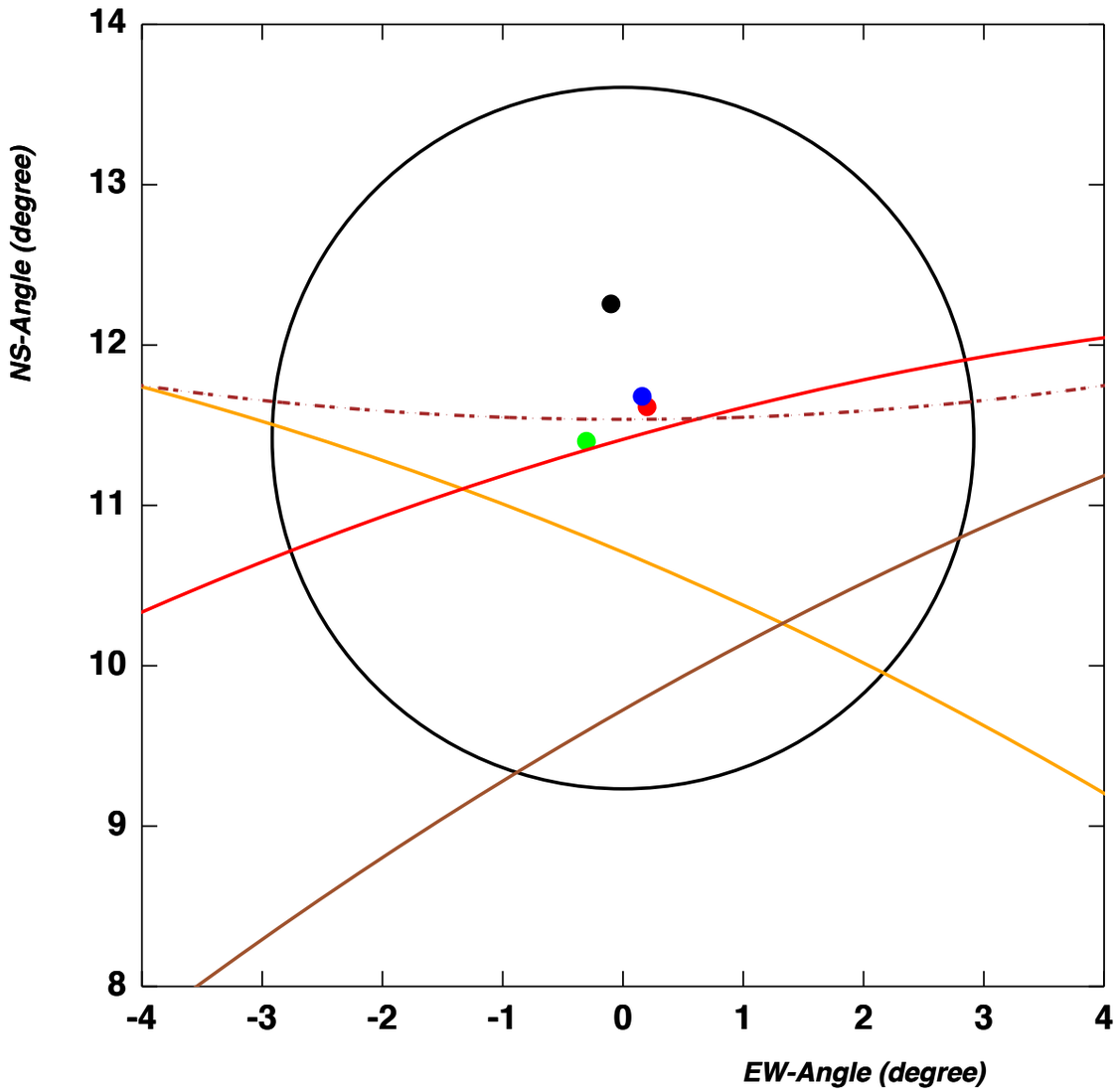
Red : PAON4 signal - Imag(visi)

Blue : Expected signal - Real

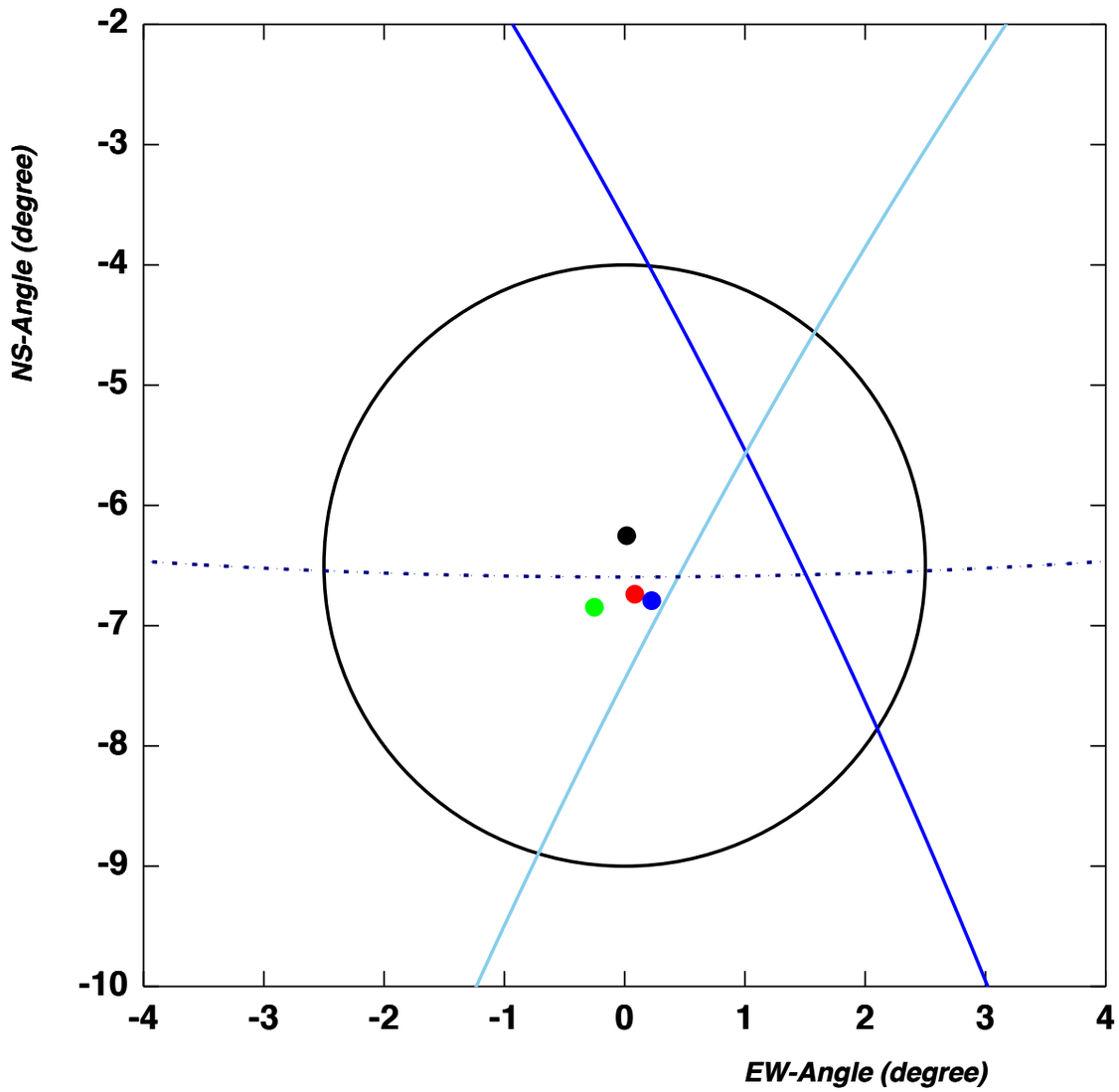
Orange : Expected signal - Imaginary

Crab @1346 MHz
Transit #2 ?

CasA , za=+11.42 deg



CygA , za=-6.5 deg



Fitted angular positions of the four PAON4 antenna (1: black, 2:red, 3:blue, 4:green) from satellite tracks