CALIBRATION AND IMAGING WITH LOFAR

Emanuela Orru'

on behalf of the Calibration and Imaging Tiger Team (CITT)

BASIC COMPONENTS

Calibration and imaging software

HBA

Goal: Facilitate the Radio Observatory to provide science ready data to users.

LBA

Goal: Find a calibration strategy for the LBA

Calibration and Imaging Tiger Team

Members

PI: Emanuela Orru'

PM: Tammo Jan Dijkema

Bas van der Tol

David Rafferty

Stefan Frohlich

Jess Broderick

Aleksandar Shulevski

Collaborators

Tim Shimwell

Andreas Horneffer

Francesco de Gasperin

Huib Intema

Maaijke Mevius

Sarod Yatawatta

Bram Veenboer

Advisory team

Francesco de Gasperin

Reinout van Weeren

Raymond Oonk

Antonia Rowlinson

David Mulcahy

Maaijke Mevius

Andre' Offringa

Busy Week 25: July 2016

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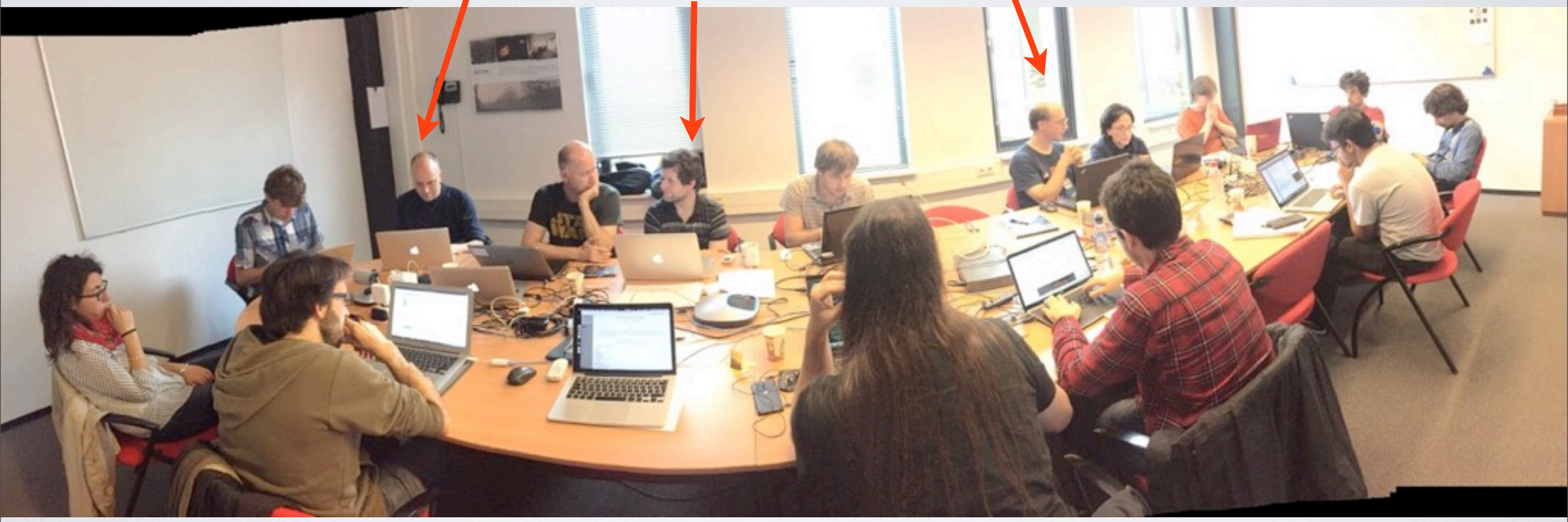
HBA



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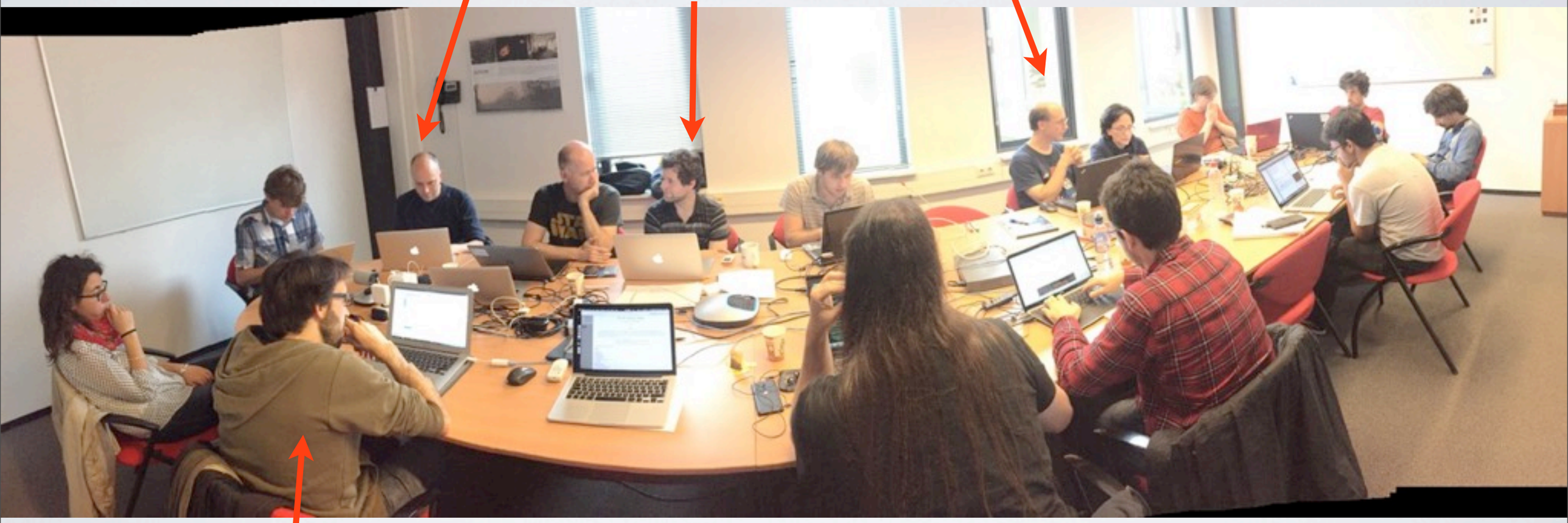

LBA

BASIC COMPONENTS

Calibration: DPPP and BBS

DPPP

- Software used to **pre-process** (flag, average, "demix") raw data
- Solver Stefcal* used to **calibrate & predict** by solving for parameters (gains, phases, amplitudes, TEC)
- Used to **apply solution** tables (parmdb) obtained with external methods (e.g. LoSoTo by F. de Gasperin)
- Faster with respect to BBS but less flexible

* Mitchell et al. 2008 Salvini & Wijnholds 2014

developed and mantained by T.J. Dijkema

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Aim for the future:

- NDPPP becomes the only software for calibration
- Increased speed and flexibility
- Preparation for calibrating the LBA
- Implementation of tools for LB calibration (fringe fitting)

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To DO

✓ investigate on DDE solver

✓ Development of TEC screen fitter

• performance

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BASIC COMPONENTS

Imaging: AWIMAGER and WSClean

IMAGER

- **Clean** secondary lobes of bright sources
- Create a **model** using cc
- **Predict** visibilities starting from cc model.
- **Apply** LOFAR **beam** (variable in time and freq.) and **phase screens.**

developed by S. van der Tol & A. Offringa + DOME project

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Used a combination **AWIMAGER** and **WSClean:** features, speed & flexibility.

✳AWIMAGER2 which includes MFS: to be imported in the production LOFAR software

✳AWIMAGER2: to be implemented multi-channel imaging

✓WSCLEAN: Average element beam correction is produced at the end of the imaging process.

✓Baseline dependent averaging implemented in WSclean and now in FACTOR

✓**Image Domain Gridder** (ref) run on GPU nodes of CEP4. Developed a software layer to tight up on wsclean.

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HBA: instrumental calibration >> pre-FACTOR

Calibrator field >> to separates contribution of the instrumental delays from the ionospheric delays

Target field >> to apply contribution of the instrumental delays and phase calibrate against a global sky model (VLSS,WENSS,NVSS & TGSS)

based on calibration scheme in van Weeren et al 2016

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Target field >> Imaging and subtraction of an high and low resolution model in preparation for Facet calibration

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HBA: direction dependent self-cal >> FACTOR

Target field >> Factor corrects for direction-dependent effects including ionospheric effects and beam-model errors.

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HBA: DIRECTION INDEPENDENT PIPELINE

instrumental calibration and imaging >> pre-FACTOR

Builded on generic pipeline in the LOFAR pipeline framework.

Calibrate the calibrator, then transfer the gain amplitudes (bandpass), clock delays and phase offsets to the target data

Direction-independent phase calibration of the target

Image and subtract sources.

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Products

- data ready to be processes with DDC-selfcal
- diagnostic plots
- the final image before the subtract step high quality adding one non direction independent self-cal loop

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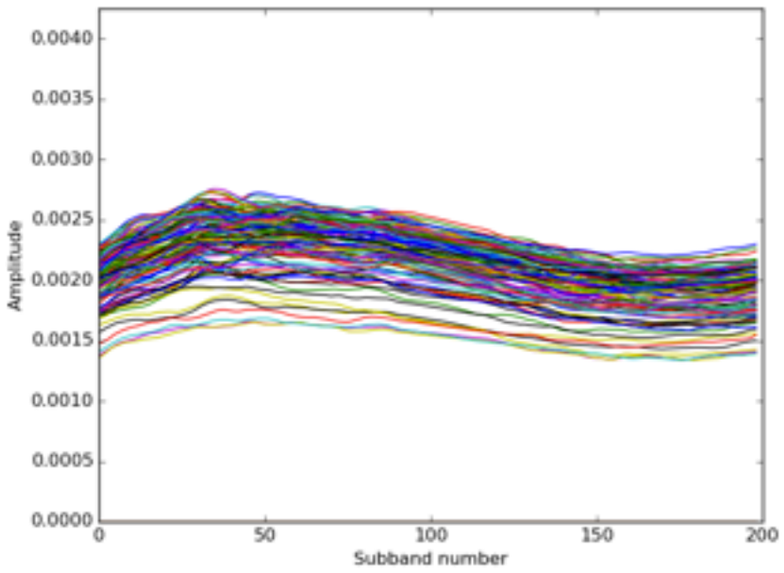
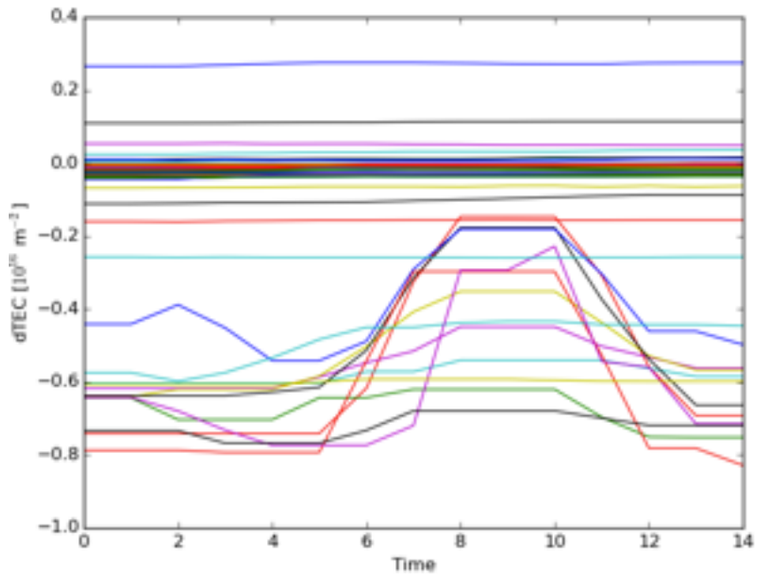
Plan

implement pre-factor in the RO pipeline replacing calibrator, target and imaging pipelines (based on gain calibration)

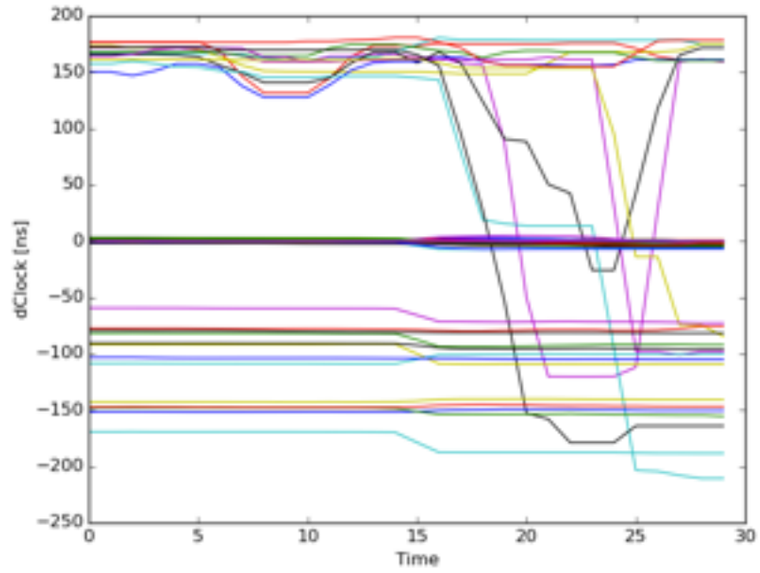
developed by A. Horneffer et al.



Amplitude

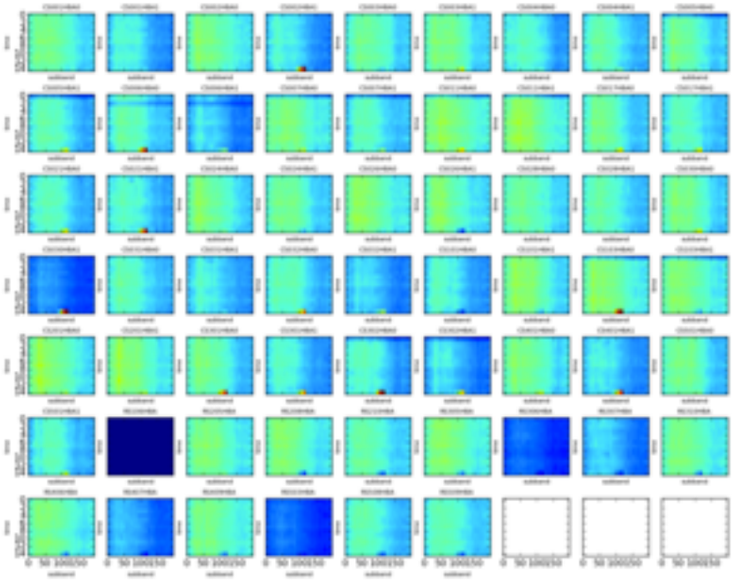


TEC delays

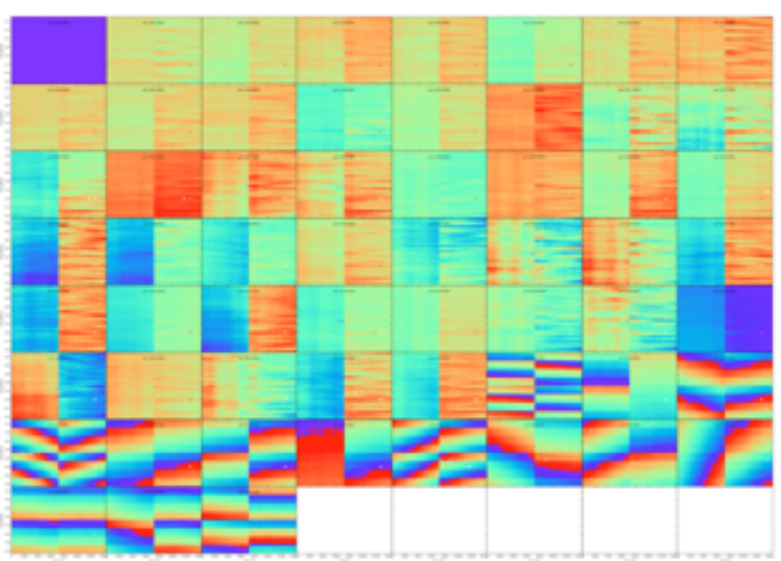


clock delays

phase offset



2d phase solutions



2d Pol solutions

HBA: **direction dependent self-cal >> FACTOR**

Target field >> Factor corrects for direction-dependent effects including ionospheric effects and beam-model errors.

By dividing up the field into many facets and solving for the direction-dependent corrections in each facet using the "peeling"

phase calibration on short time scale >> ionospheric effects
amplitude calibration long time scale >> residual beam errors

Supports interleaved and multi-night datasets as well as continuous observations.

designed to distribute of jobs over multiple nodes of a cluster and for the processing of facets in parallel.

developed by D. Rafferty

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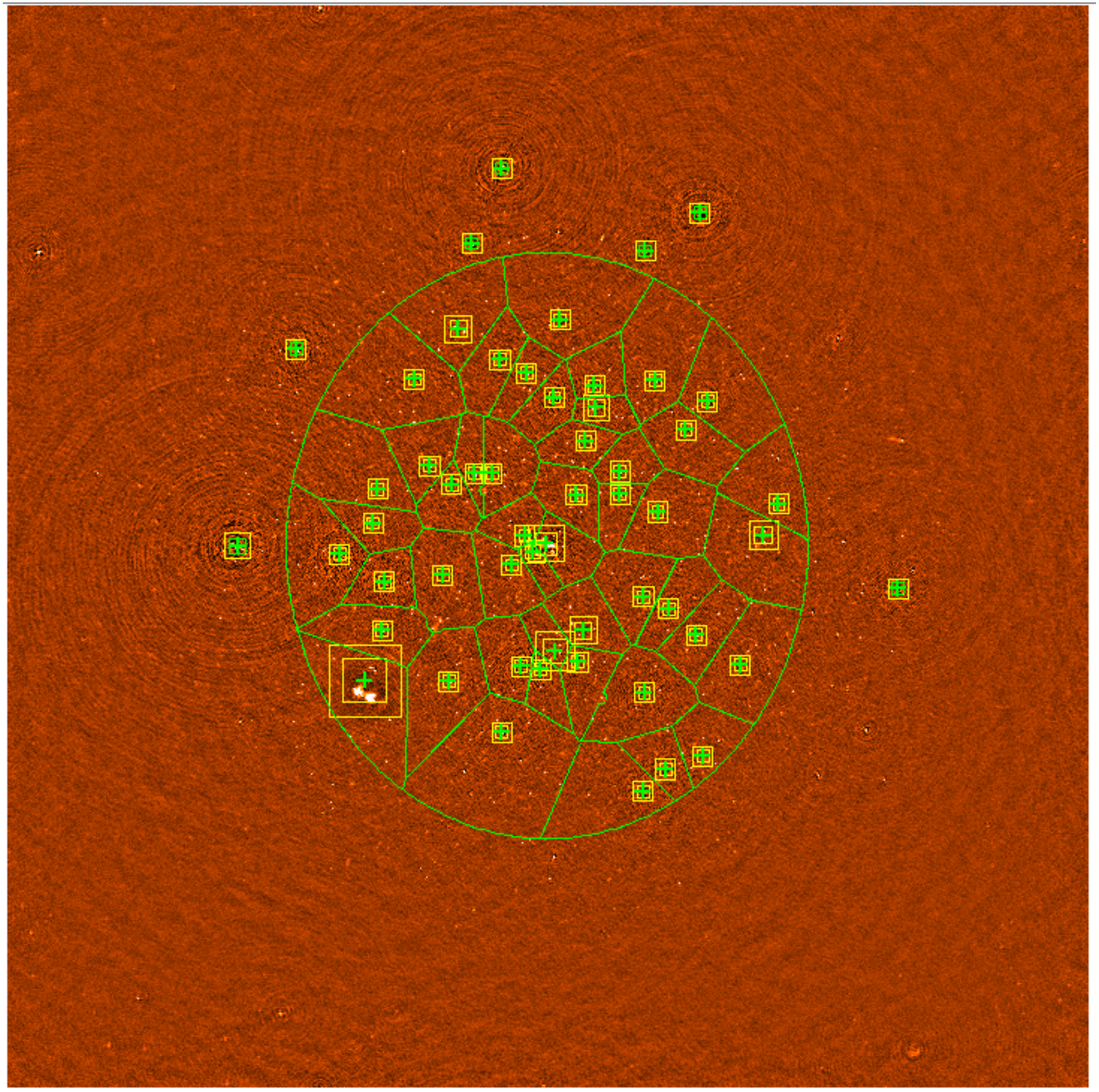
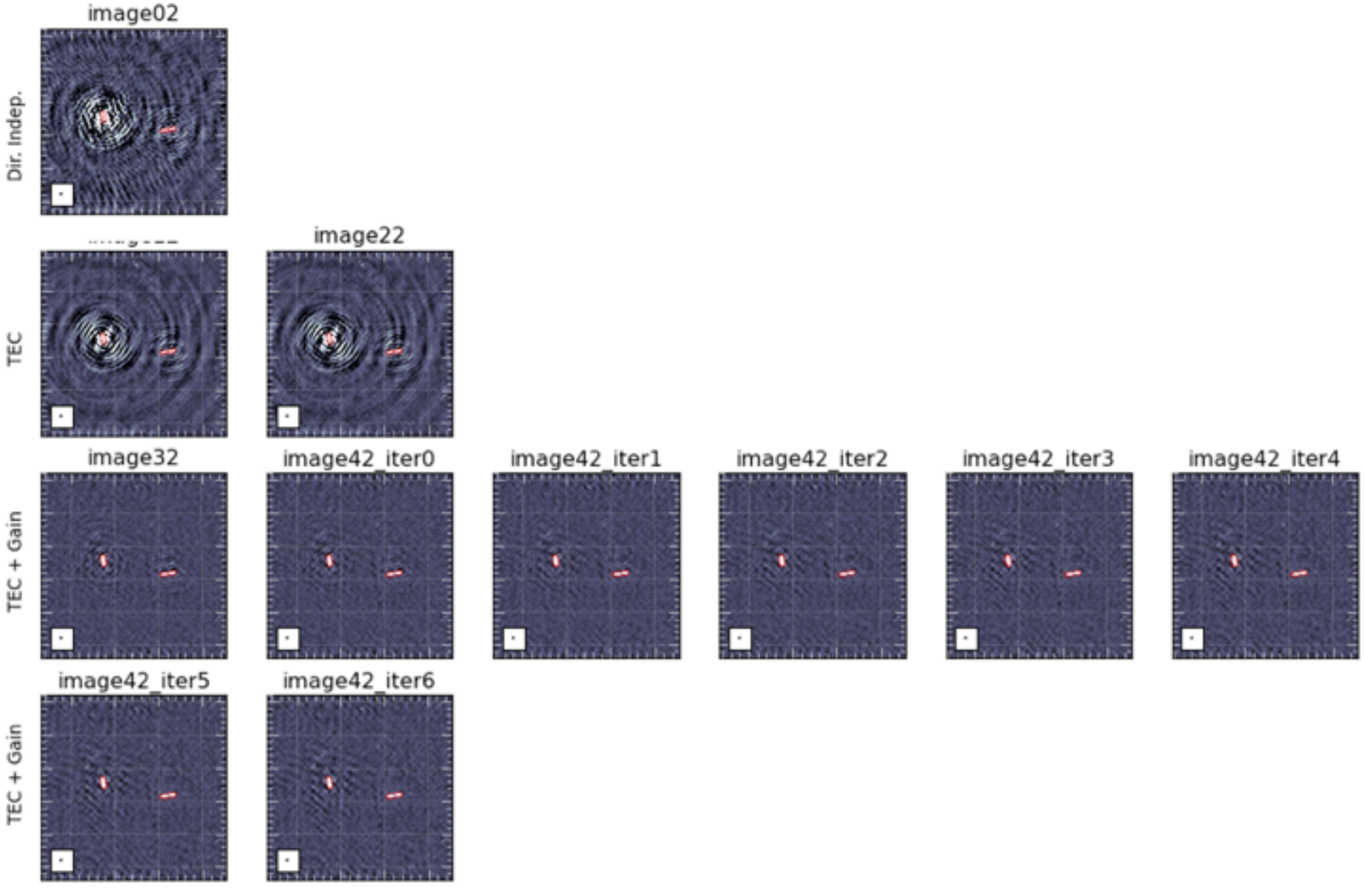
TO DO

- complete the commissioning discuss features for initial release & organization of data-product
- add intelligence (calibrator choice, bad data excision..)

developed by D. Rafferty



calibrator selfcal images for selected direction
facet image for selected direction
TEC solutions for selected direction
Gain solutions for selected direction



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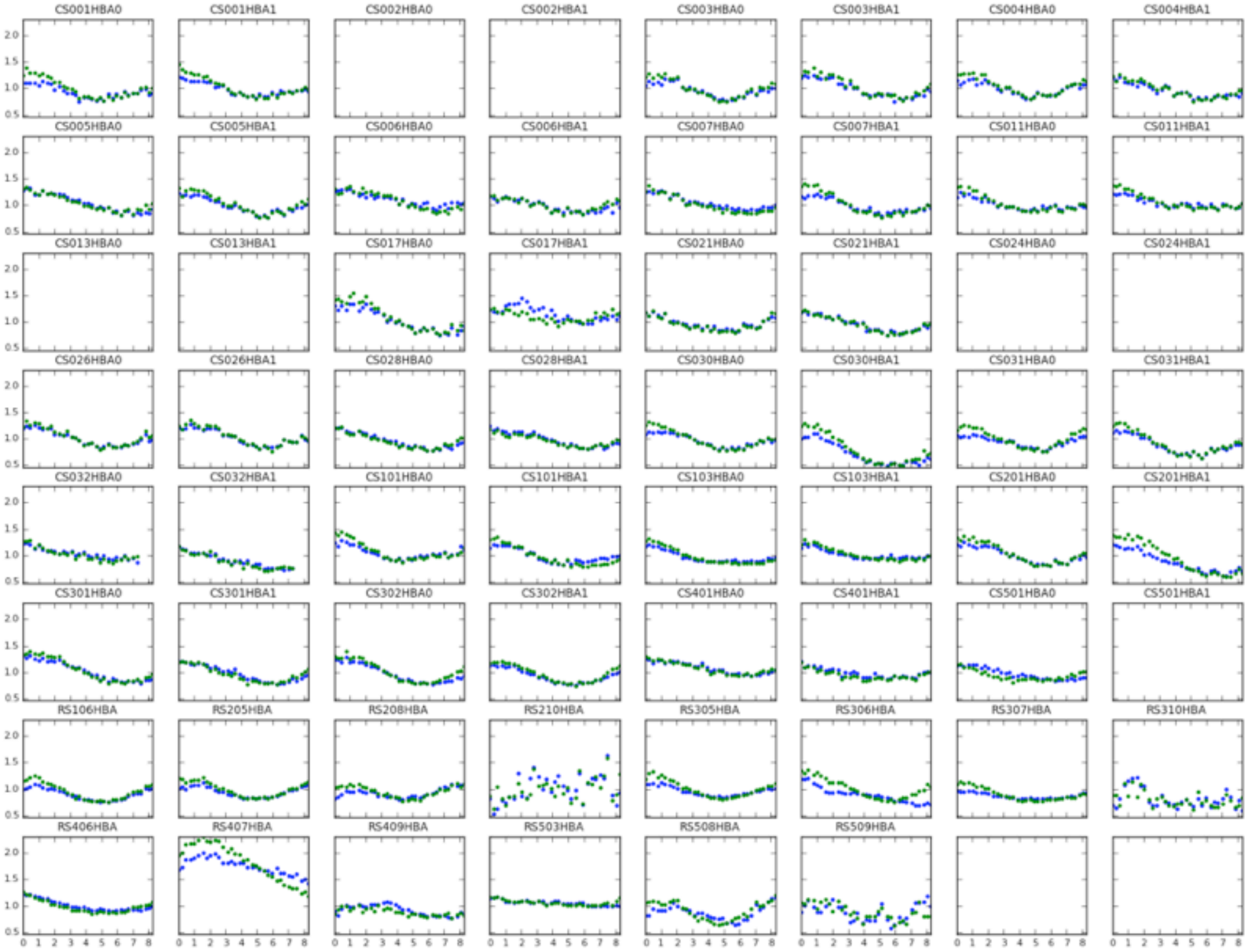

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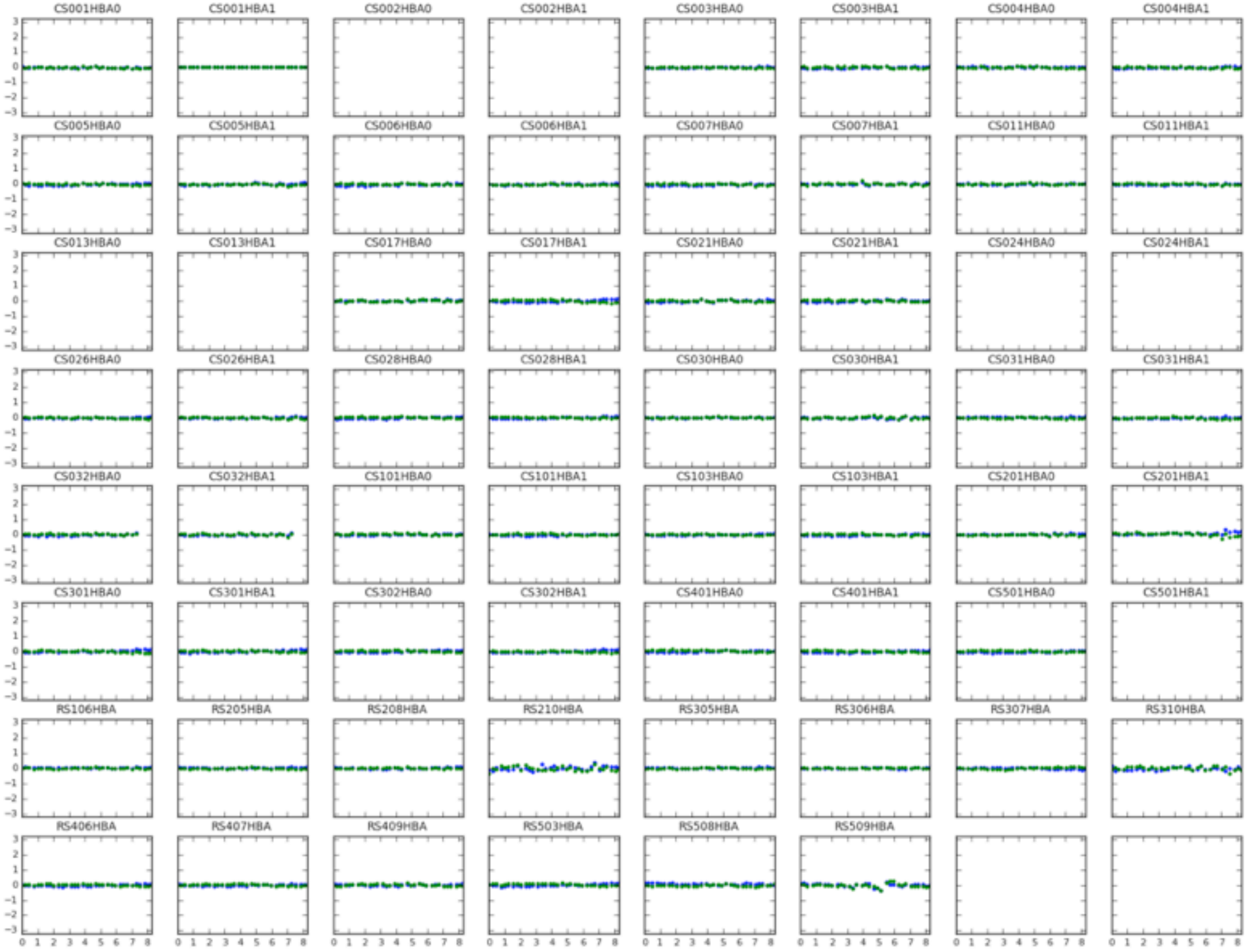

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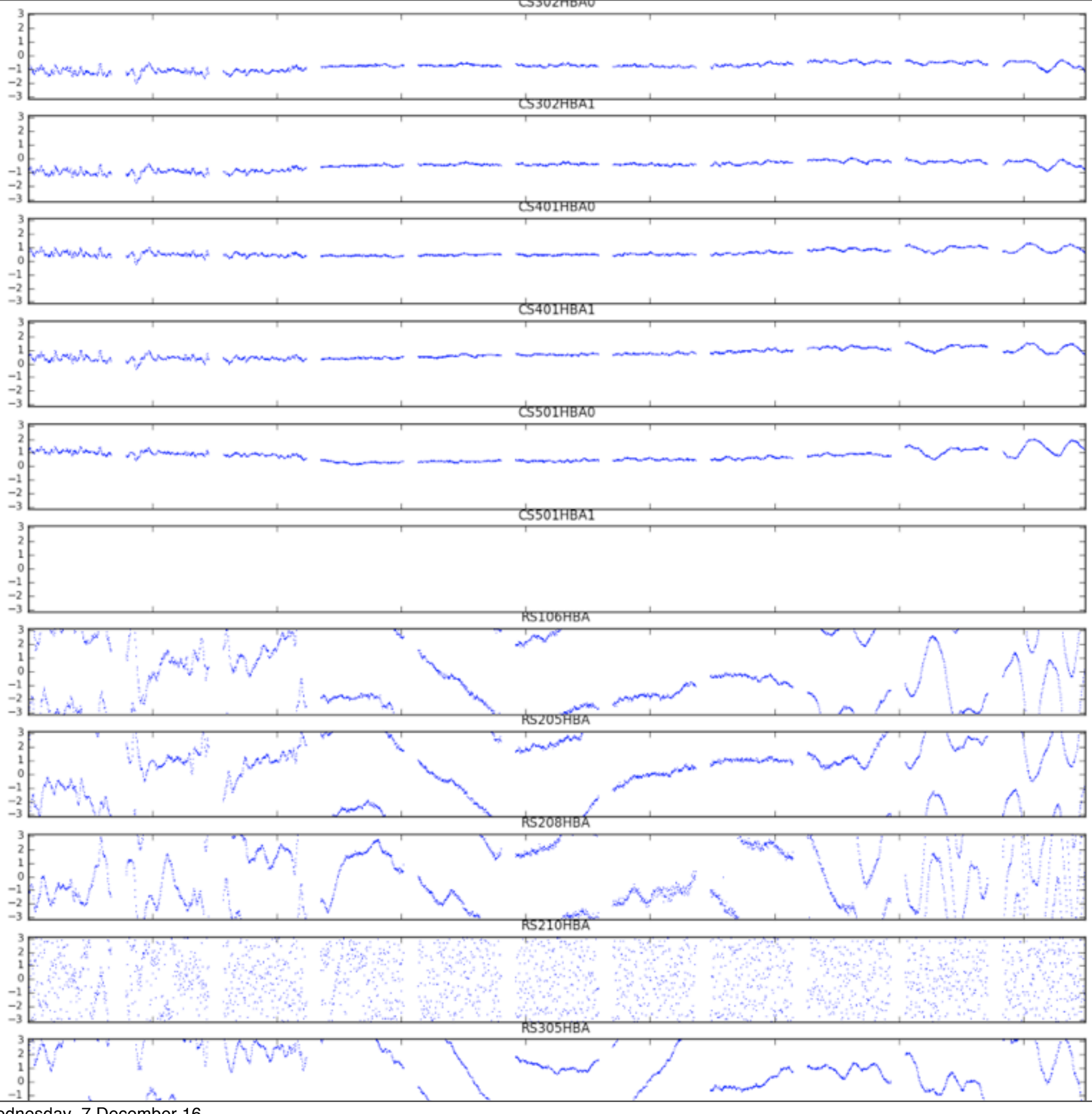
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CS401HBA0
CS401HBA1
CS501HBA0
CS501HBA1
RS106HBA
RS205HBA
RS208HBA
RS210HBA
RS305HBA

LBA

Calibrator field >> to separates contribution of the instrumental delays from the ionospheric delays and calculate bandpass gains
Target field >> fit a TEC screen

✓ DFR is solved both for the calibrator and target field.

✓ Calibrate the calibrator, then transfer the bandpass clock delays and phase offsets to the target data

✳ Direction-dependent calibration of the target solving for the TEC over the all bandwidth for few calibrator sources

✳ Fit a TEC screen

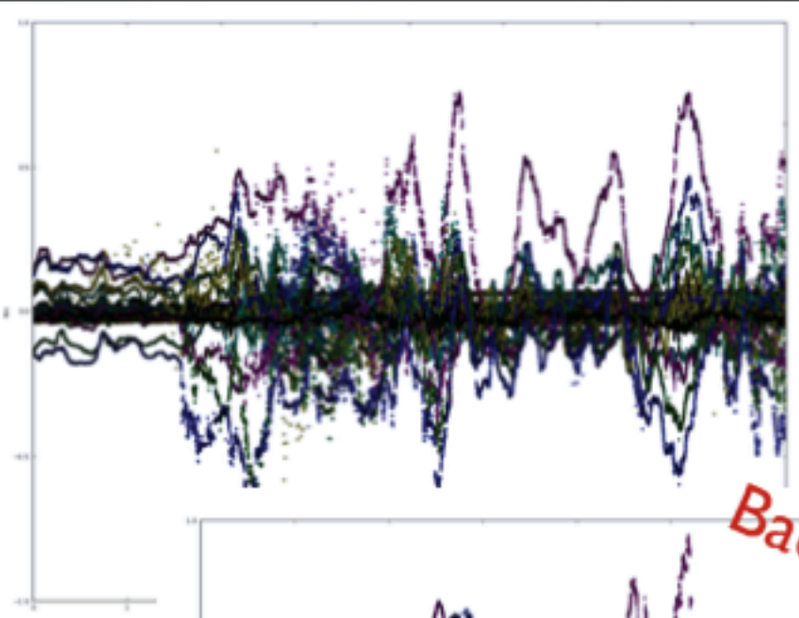
Plan

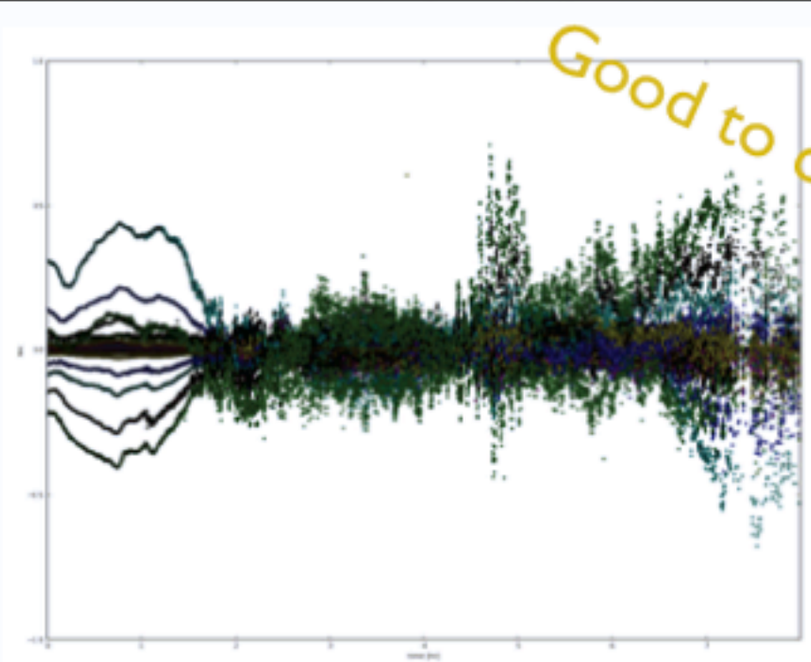
Find a calibration procedure for the target field
Work in a close contact with ionospheric physicists

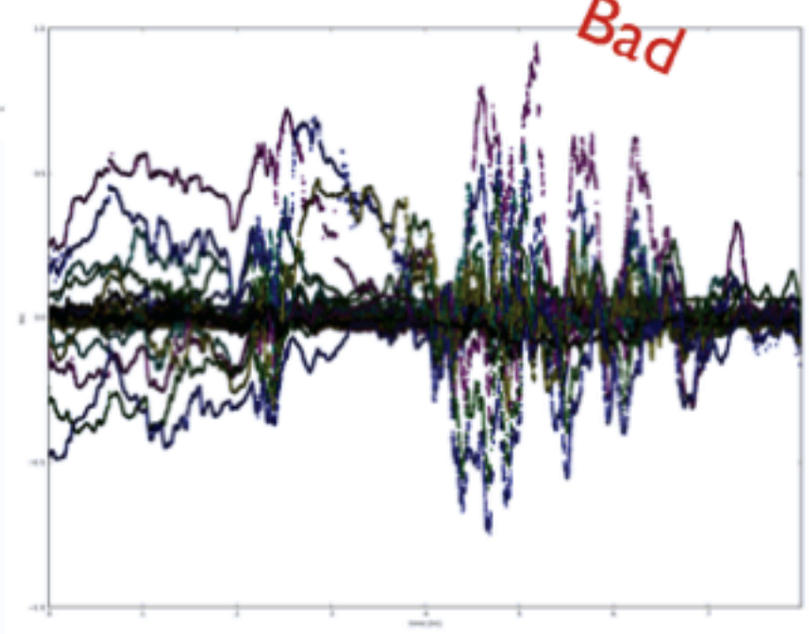
Status:

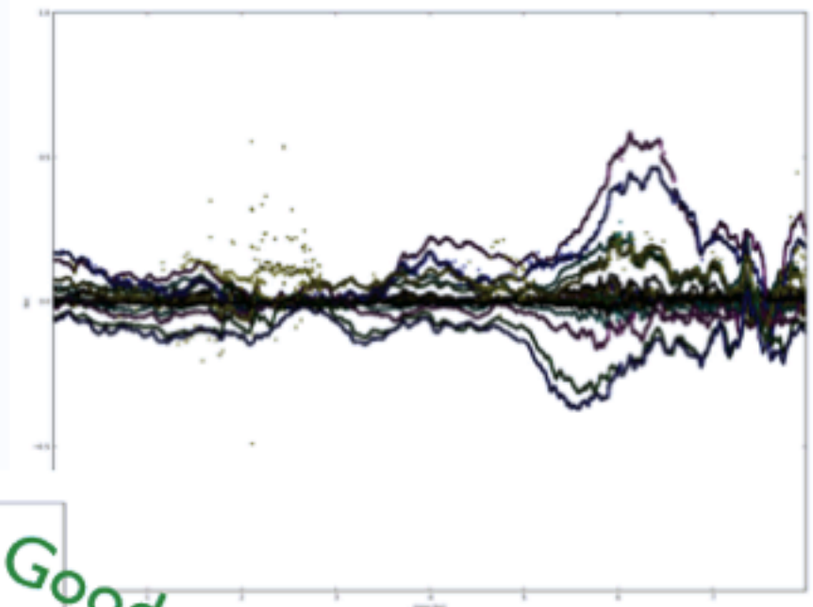
- difficult to understand how to tackle scintillation since it is DDE
- *Low S/N and high decorrelation complicate the scenario*

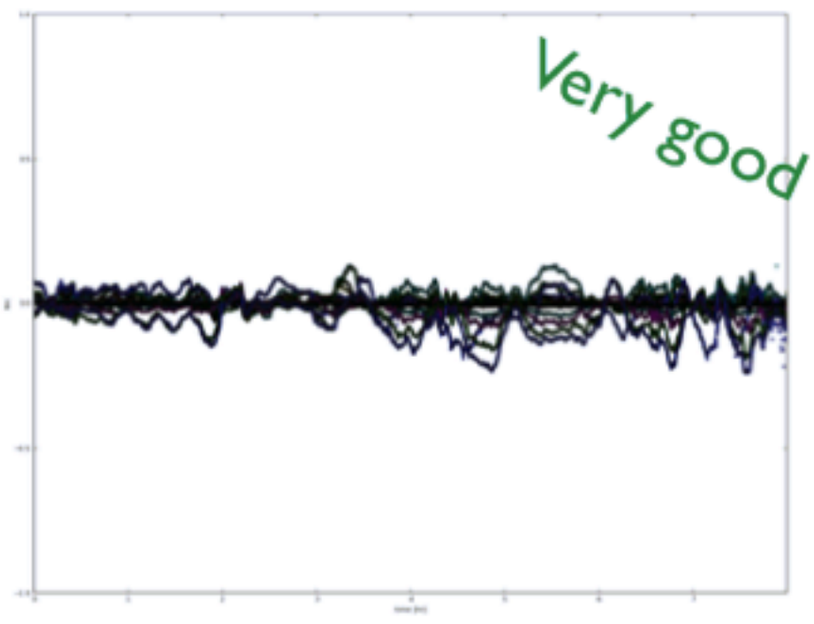
developed by F. de Gasperin

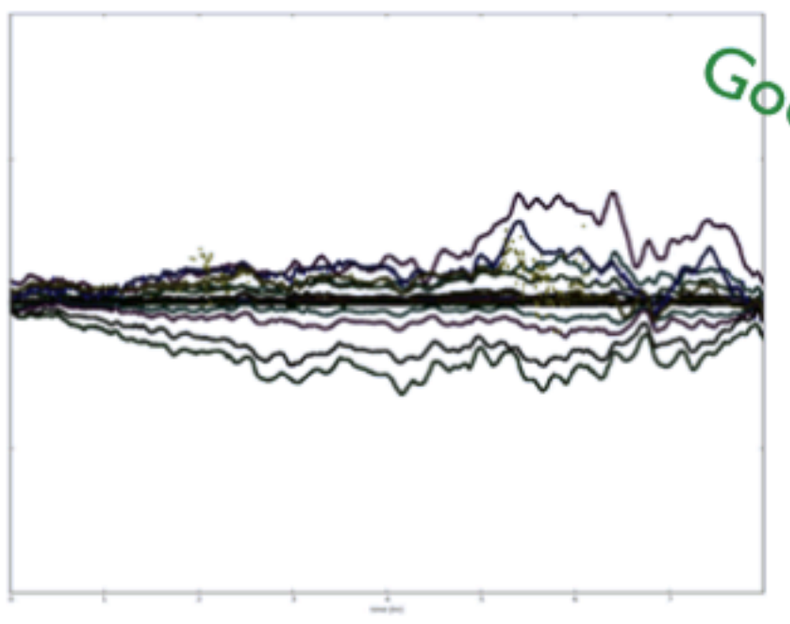


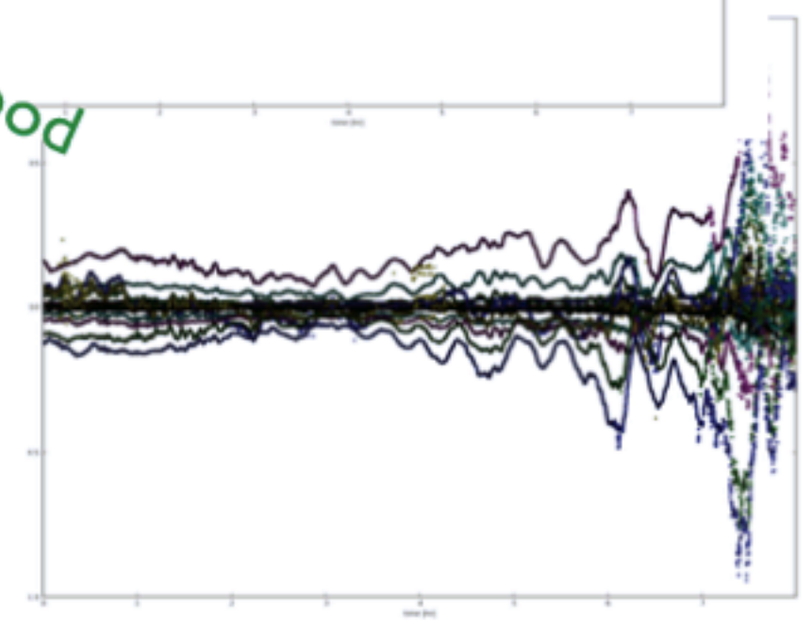












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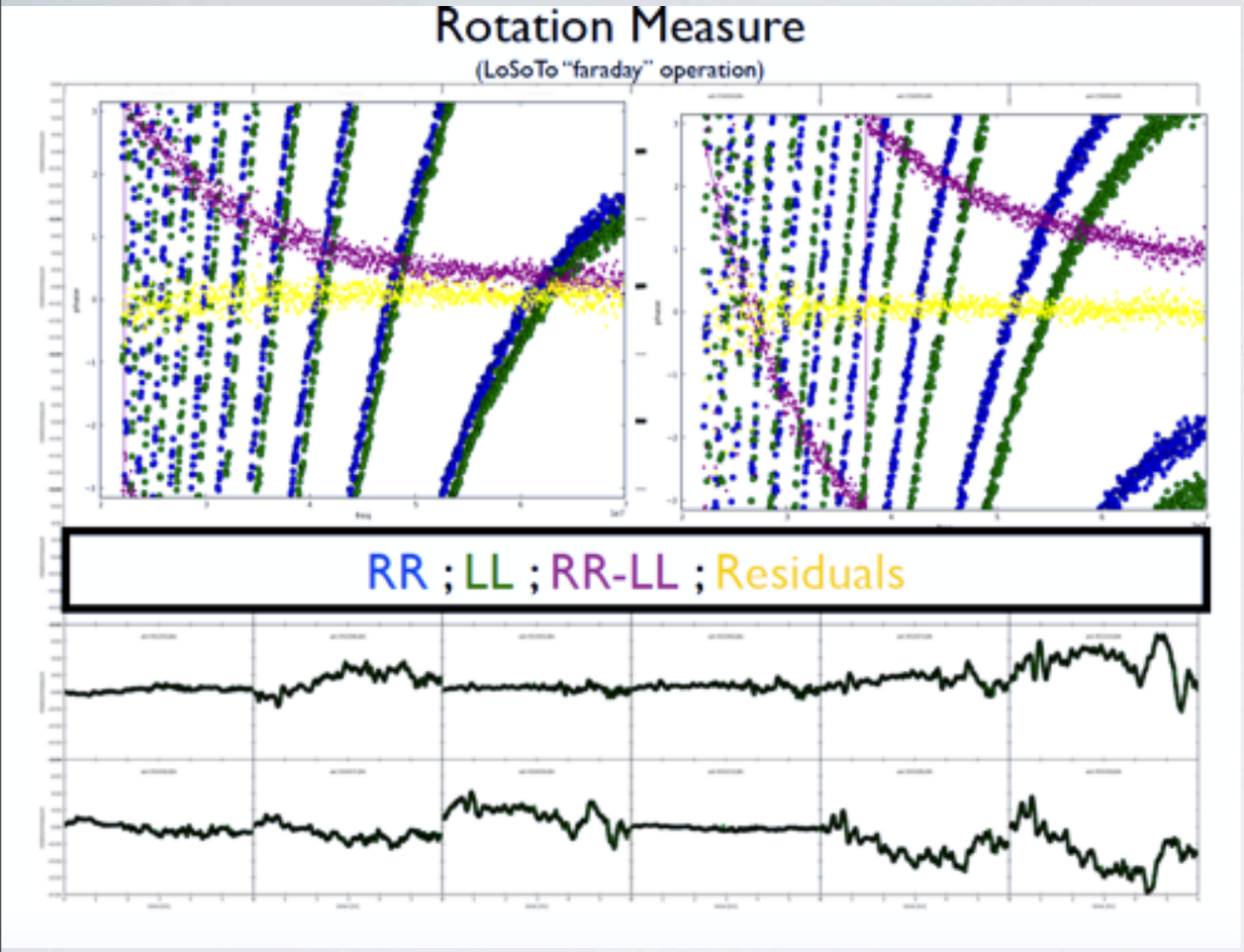
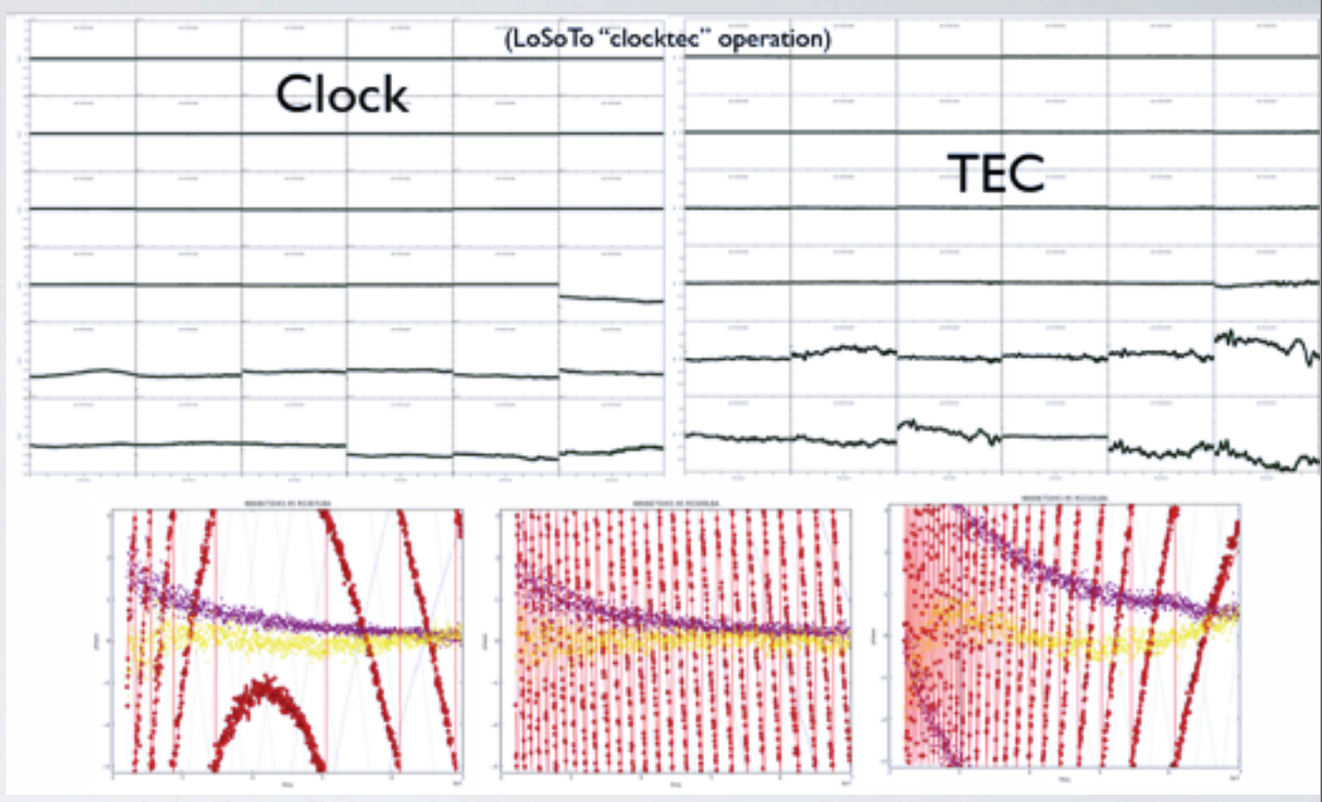


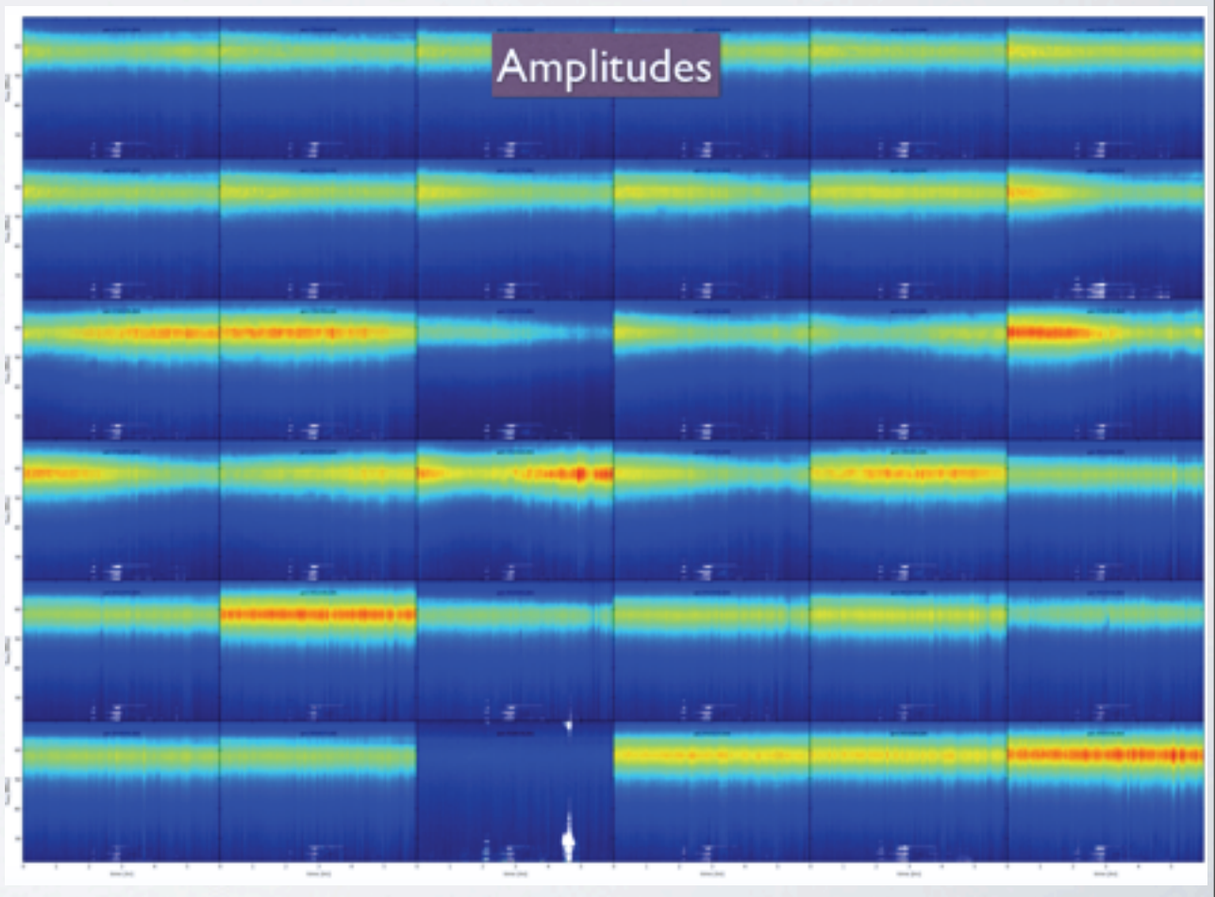


Calibrator:

- ✓ Strategy F. de Gasperin transported to a pipeline Pill (similar to HBA).
- ✓ Being tested & still subject to changes.

Target:

- ✓ Ongoing investigation of DDC: Factor, KillMS, Sagecal & SPAM
- ✓ New features in LoSoTo to get ionospheric diffractive scales.



CONCLUSIONS

✓BBS almost replaced by DPPP

✓IDG being tested on wsclean

✓**prefactor pipeline ready to become part of RO processing**

✓**FACTOR pipeline ready to be used by general users. Provides science ready data**

✓LBA fully understood phase and amp in calibrator field.

✓ LBA target field under investigation methods for simultaneous DDC