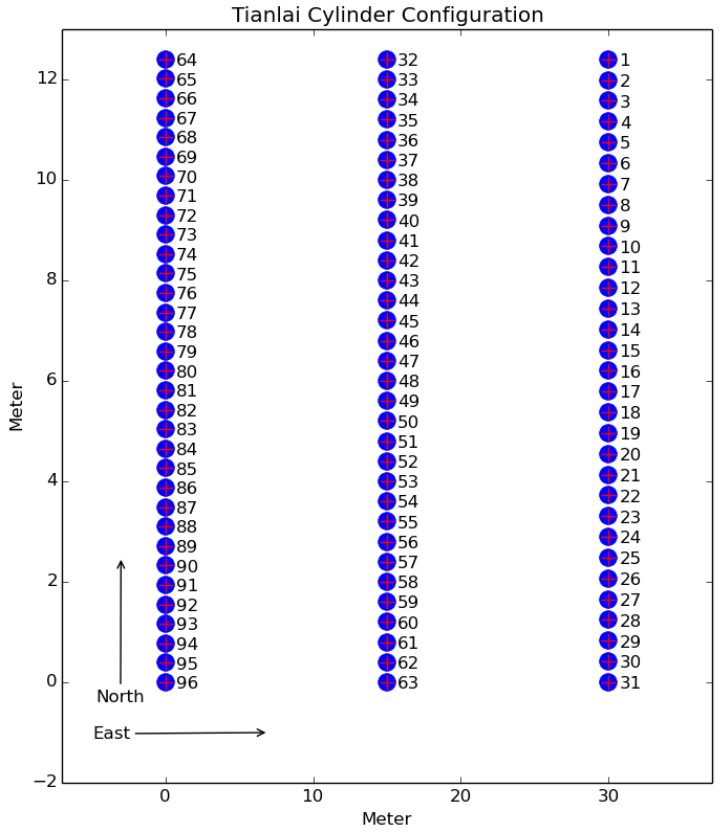
Tianlai Data Processing: For data observed in 2016/08/29

Fengquan Wu, Shifan Zuo, Qizhi Huang

Tianlai Cylinder Feed Configuration



Data Format --- HDF5

- Radio Data format varied a lot
- HDF5: parallel reading/writing
- Defined a number of attributes
- Finalizing the format defination

File: 20160830124922_20160830125921.hdf5

Top level attributes

/.attrs["comment"]: 28hr obs
/.attrs["telescope"]: Tianlai-Cylinder-I
/.attrs["observer"]: Fengquan Wu
/.attrs["siteelev"]: 1493.7
/.attrs["samplingbits"]: 8
/.attrs["cywid"]: 15.0
/.attrs["nfeeds"]: 96
/.attrs["timezone"]: UTC+08h
/.attrs["corrver"]: 0.0
/.attrs["nants"]: 3
/.attrs["nfreq"]: 1008
/.attrs["lofreq"]: 935.0
/.attrs["sitename"]: Hongliuxia Observatory
/.attrs["inttime"]: 3.99507456
/.attrs["epoch"]: 2000.0
/.attrs["keywordver"]: 0.0
/.attrs["corrmode"]: 1
/.attrs["dishdiam"]: 6.0
/.attrs["sec1970"]: 1472532562.42
/.attrs["freqstart"]: 685.0
/.attrs["obstime"]: 2016/08/30 12:49:22.415561
/.attrs["nickname"]: 28hr obs
/.attrs["freqstep"]: 0.1220703125
/.attrs["npols"]: 2
/.attrs["recvver"]: 0.0
/.attrs["sitelon"]: 91.80686667
/.attrs["cylen"]: 40.0
/.attrs["history"]: Recorded from the correlator. Transformed from raw format
/.attrs["sitelat"]: 44.15268333

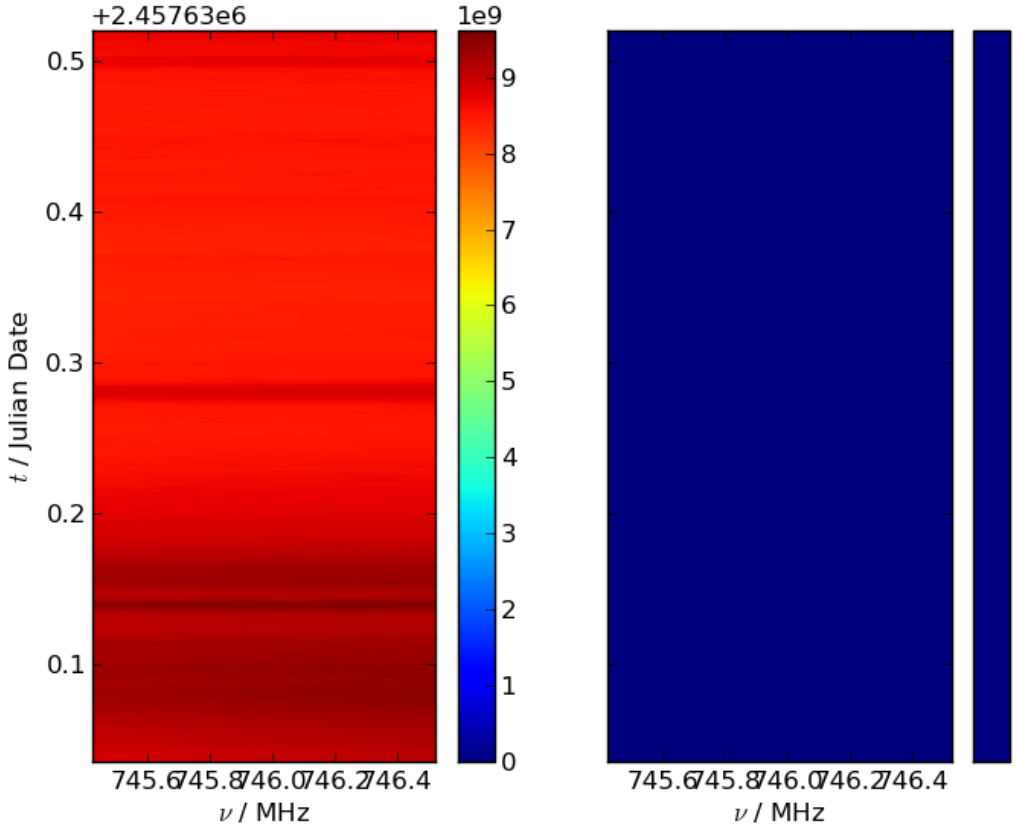
Data Format --- HDF5

File: 20160830124922_20160830125921.hdf5

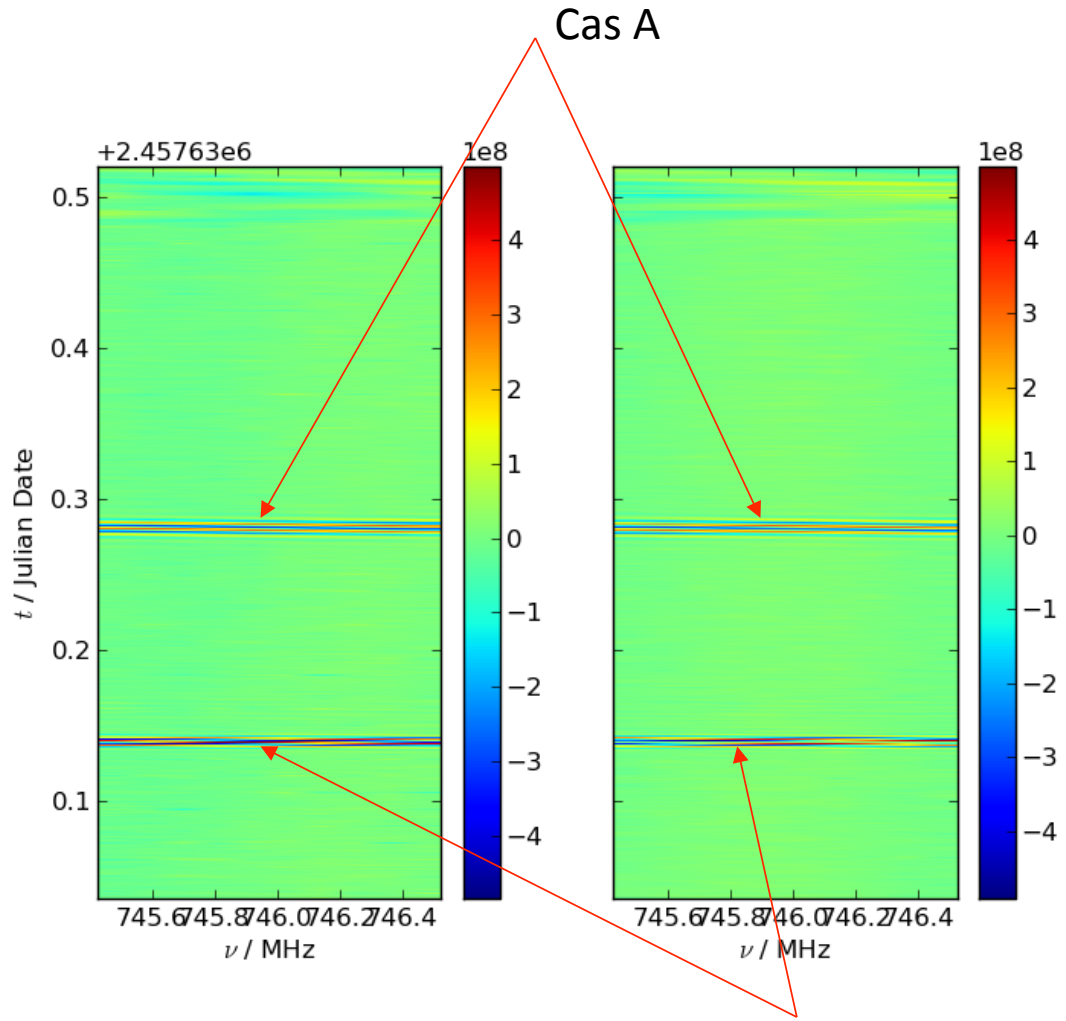
Top level dataset

blorder shape = (18528, 2)
channo shape = (96, 2)
channo.attrs["dimname"]: Feed No., (Channel No. of Xpol, Channel No. of Ypol)
feedno shape = (96,)
feedpos shape = (96, 3)
feedpos.attrs["dimname"]: Feed No., (X, Y, Z) coordinate
feedpos.attrs["unit"]: meter
noisesource shape = (1, 3)
noisesource.attrs["dimname"]: NoiseSource No., (Start, Stop, Cycle)
noisesource.attrs["unit"]: second
nspos shape = (3, 3)
nspos.attrs["dimname"]: NoiseSource No., (X, Y, Z) coordinate
nspos.attrs["unit"]: meter
vis shape = (150, 1008, 18528)
vis.attrs["dimname"]: Time, Frequency, Baseline

Visibility



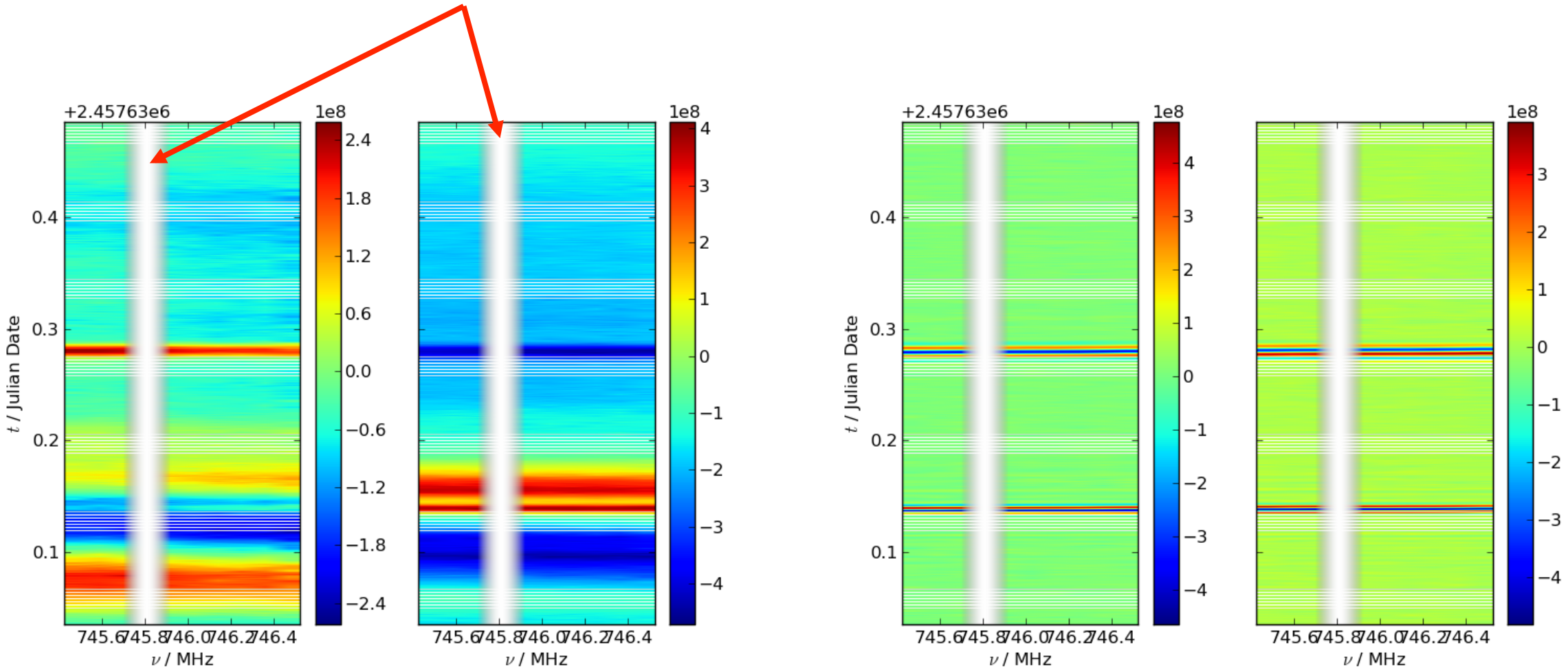
Auto-correlation



Cross-correlation

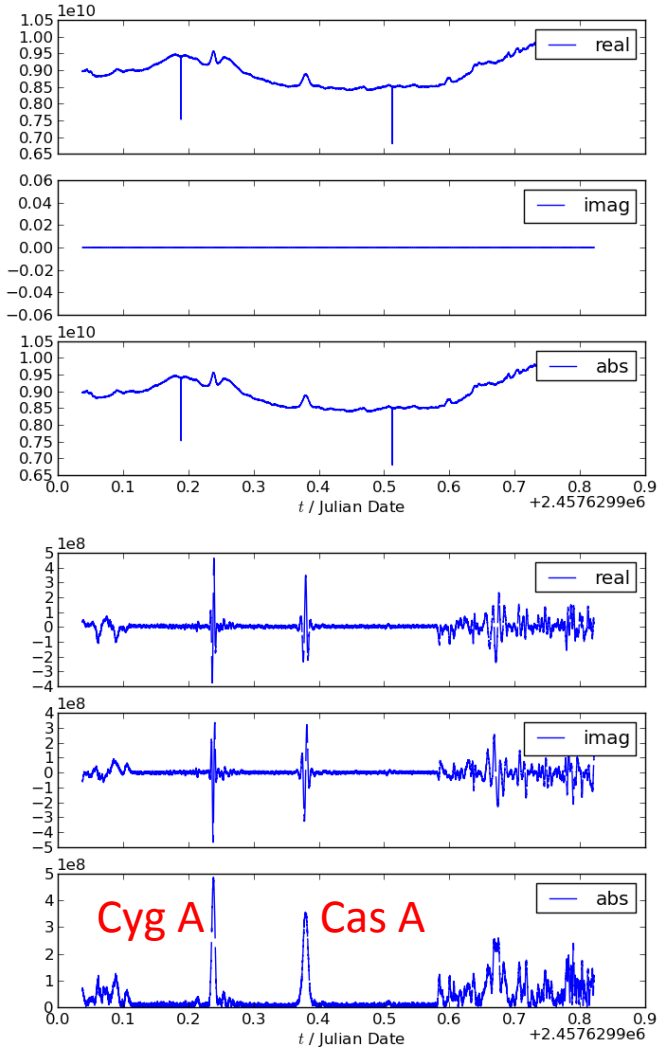
Cyg A

Data lost


Data lost
+2.45763e6
1e8
t / Julian Date
0.4
0.3
0.2
0.1
2.4
1.8
1.2
0.6
0.0
−0.6
−1.2
−1.8
−2.4
4
3
2
1
0
−1
−2
−3
−4
745.6
745.8
746.0
746.2
746.4
ν / MHz

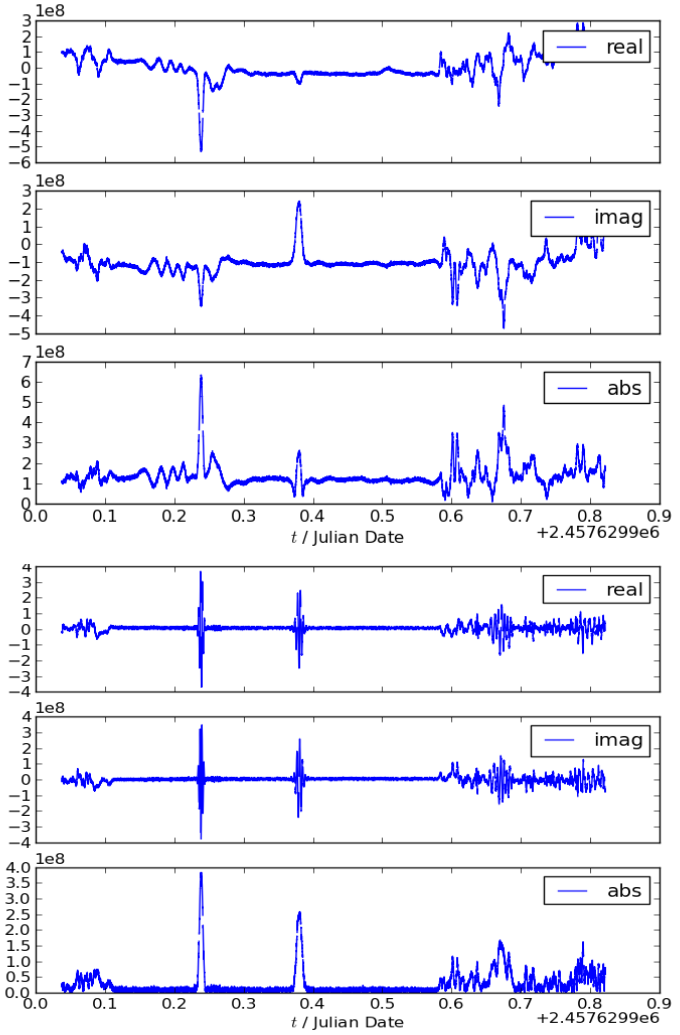
Frequency Integration of Visibility

Auto-correlation



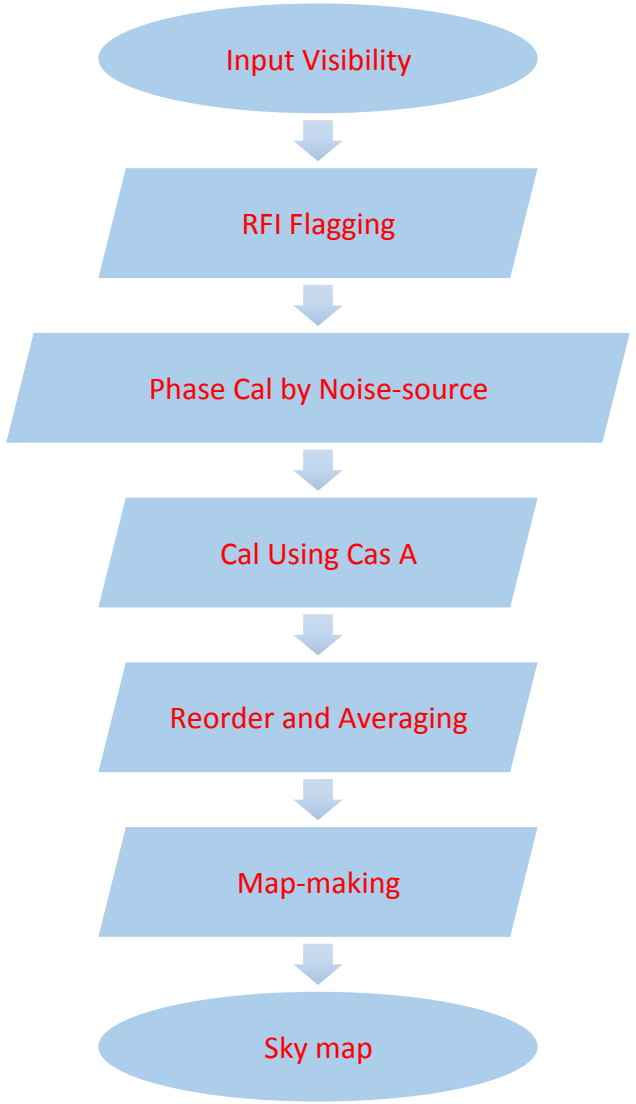
East-west 15m

North-south 2.8m



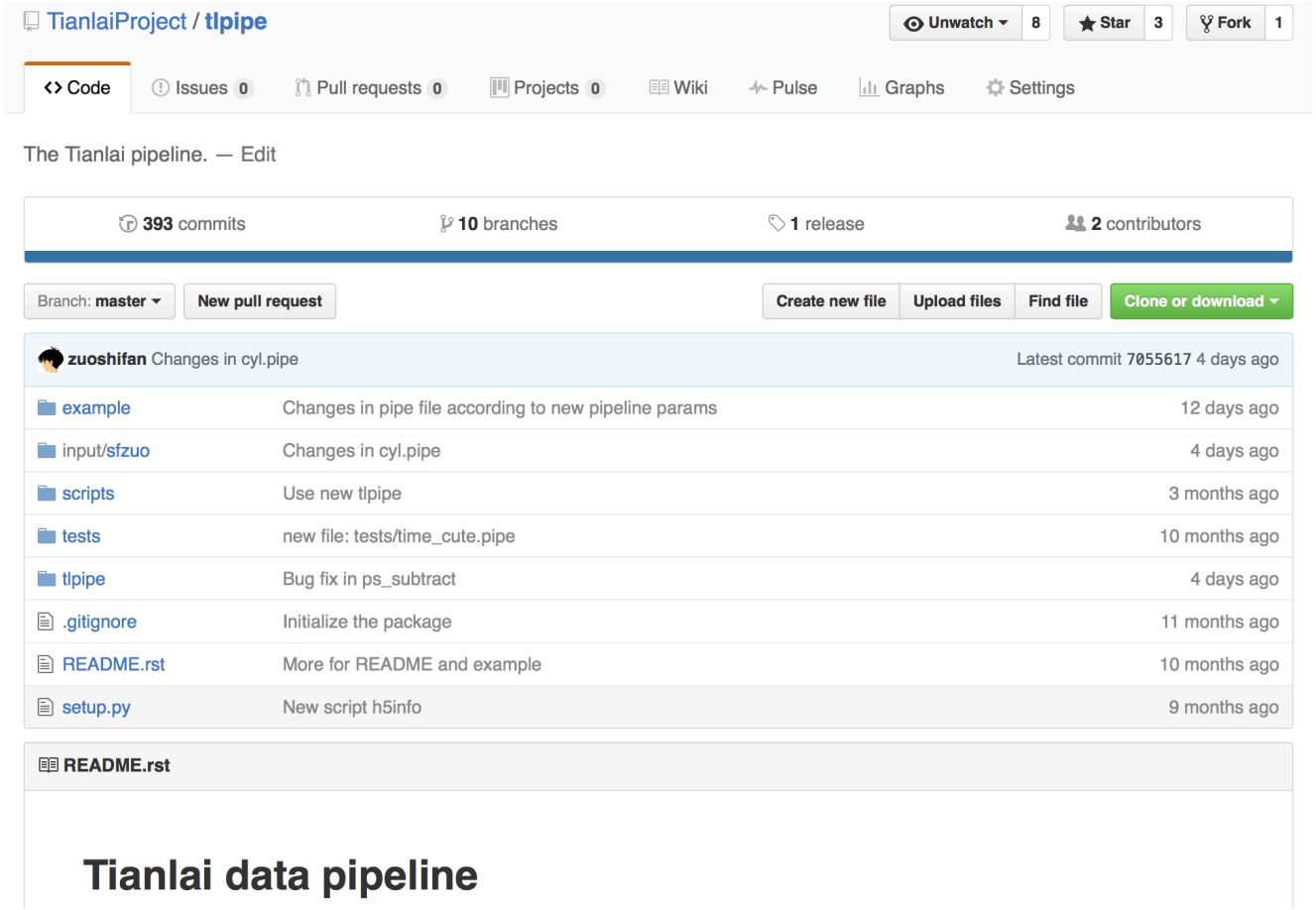
East-west 30m

Data Processing Pipeline



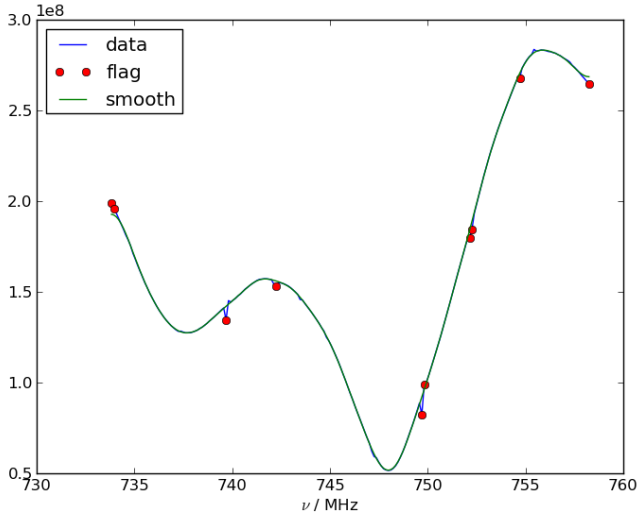
Data Processing Software

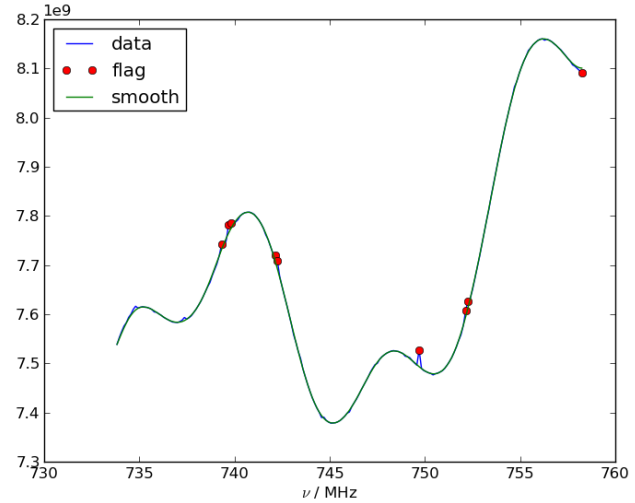
https://github.com/TianlaiProject/tlpipe

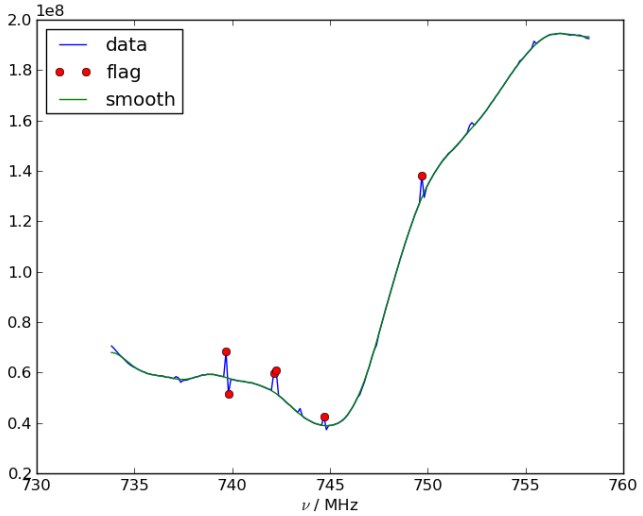


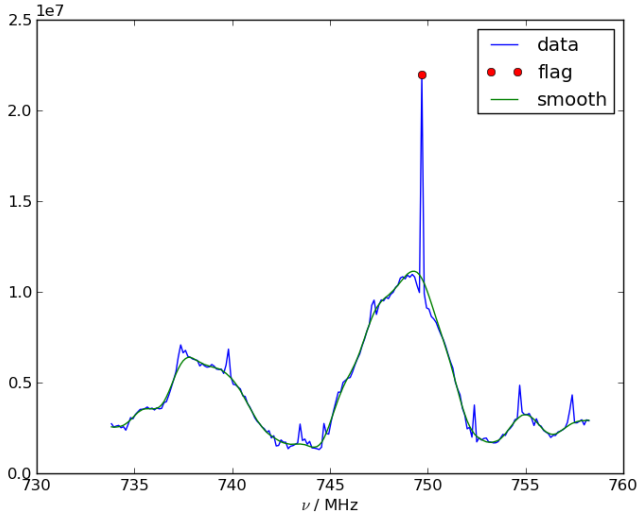
RFI Flagging Along Frequency

Non-flat and non-smoothing bandwidth hampers the RFI flagging



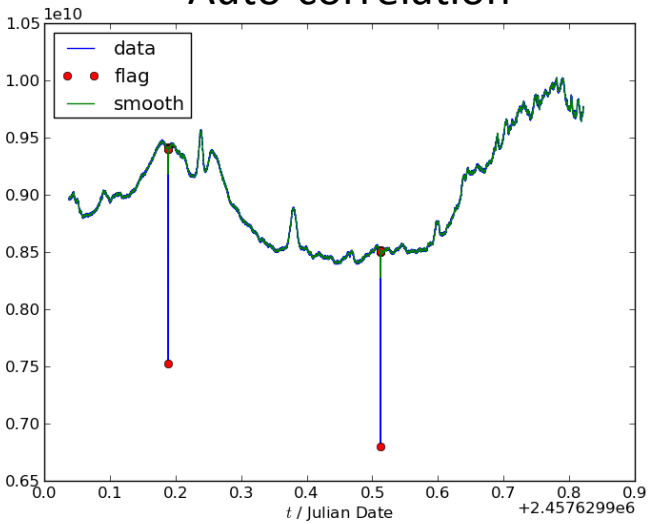




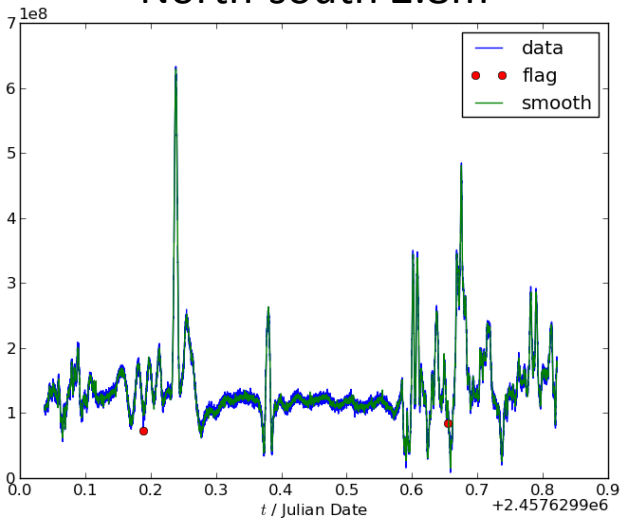


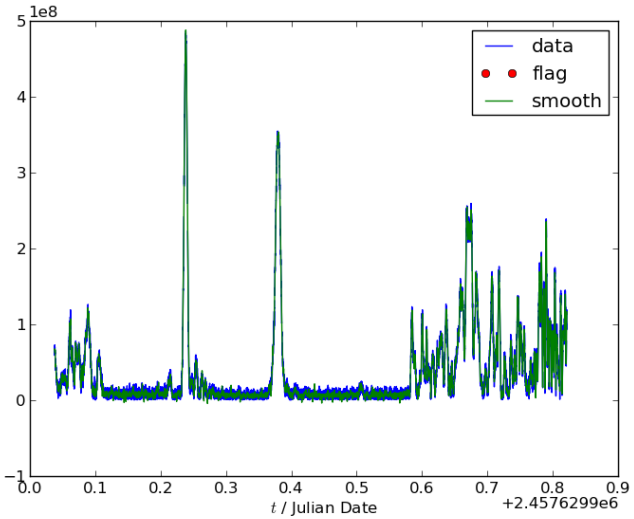
RFI Flagging Along Time

Auto-correlation

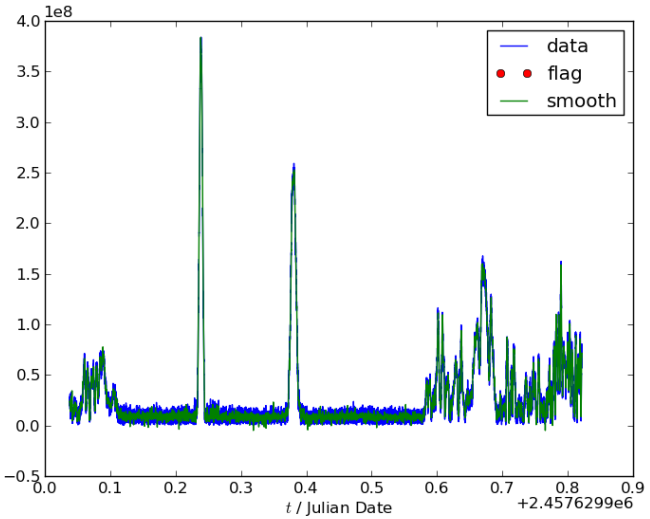


North-south 2.8m





East-west 15m



East-west 30m

Relative Phase Calibration Using Noise Source

The noise source can be viewed as a near-field source, its visibility can be expressed as

$$V_{ij}^{\mathrm{ns}} = C \cdot e^{ik(r_i - r_j)}$$

where C is a real constant.

$$\begin{aligned} V_{ij}^{\mathrm{on}} &= G_{ij}(V_{ij}^{\mathrm{sky}} + V_{ij}^{\mathrm{ns}} + n_{ij}) \\ V_{ij}^{\mathrm{off}} &= G_{ij}(V_{ij}^{\mathrm{sky}} + n_{ij}) \end{aligned}$$

where G_{ij} is the gain of baseline i, j.

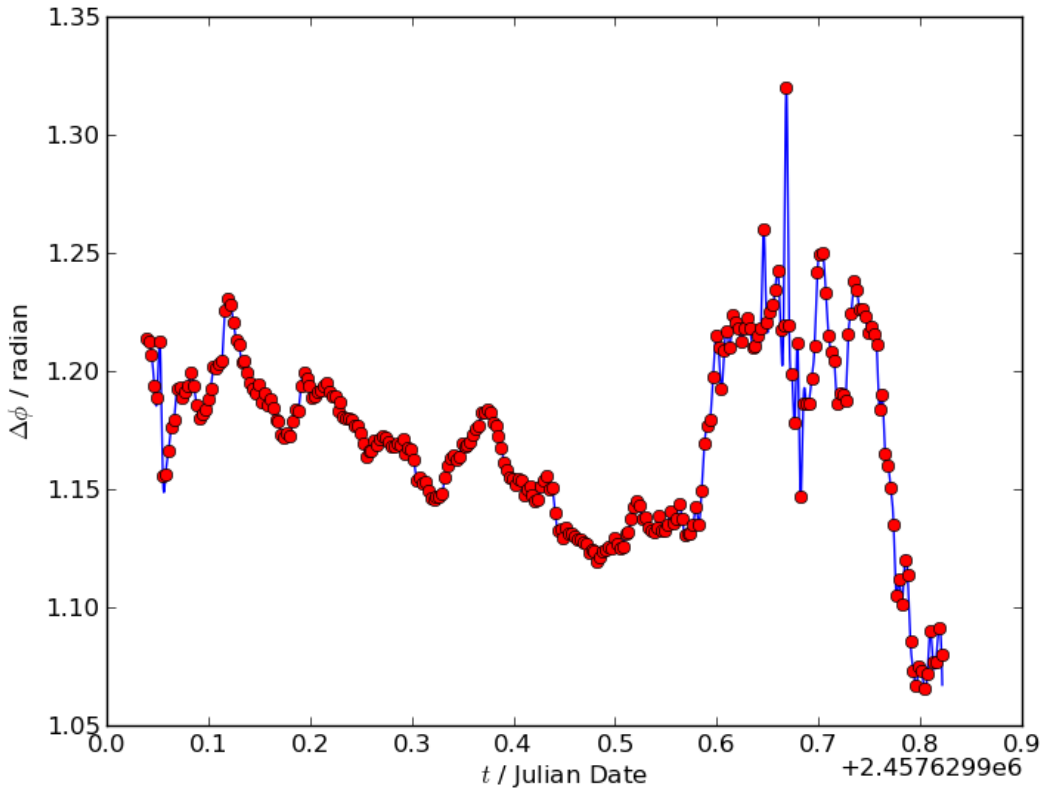
$$\begin{aligned} V_{ij}^{\mathrm{on}} - V_{ij}^{\mathrm{off}} &= G_{ij} V_{ij}^{\mathrm{ns}} \\ &= |G_{ij}| e^{ik\Delta L} C \cdot e^{ik(r_i - r_j)} \\ &= C|G_{ij}| e^{ik(\Delta L + (r_i - r_j))} \end{aligned}$$

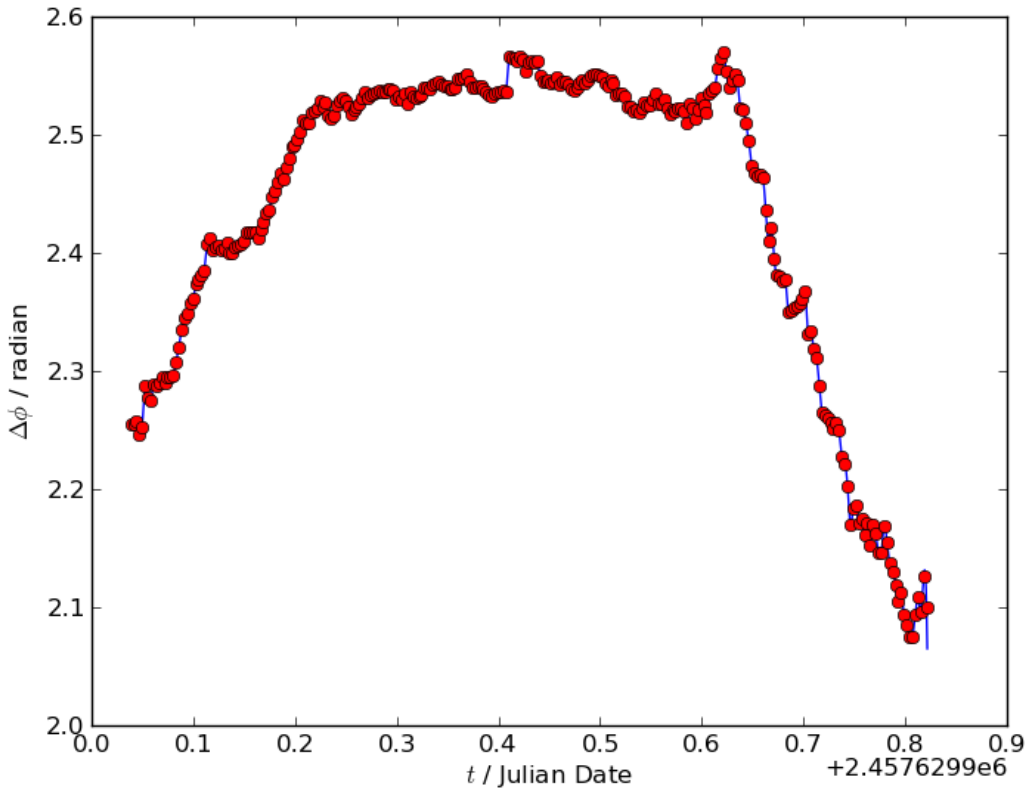
where ΔL is the cable length.

$$\mathrm{Arg}(V_{ij}^{\mathrm{on}} - V_{ij}^{\mathrm{off}}) = k(\Delta L + (r_i - r_j)) = k\Delta L + const.$$

Relative Phase Calibration Using Noise Source

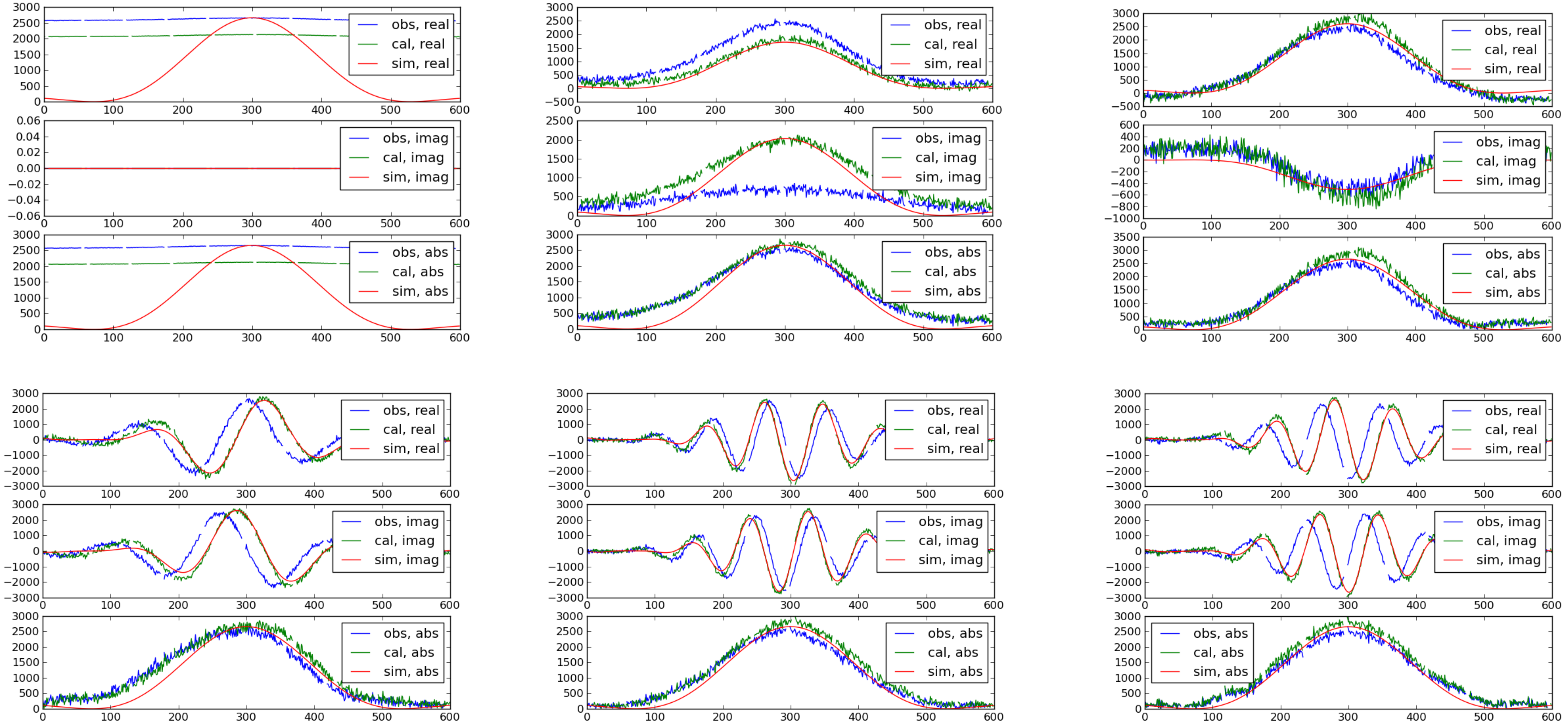
$$\Delta\phi = \mathrm{Arg}(V^{\mathrm{on}} - V^{\mathrm{off}})$$





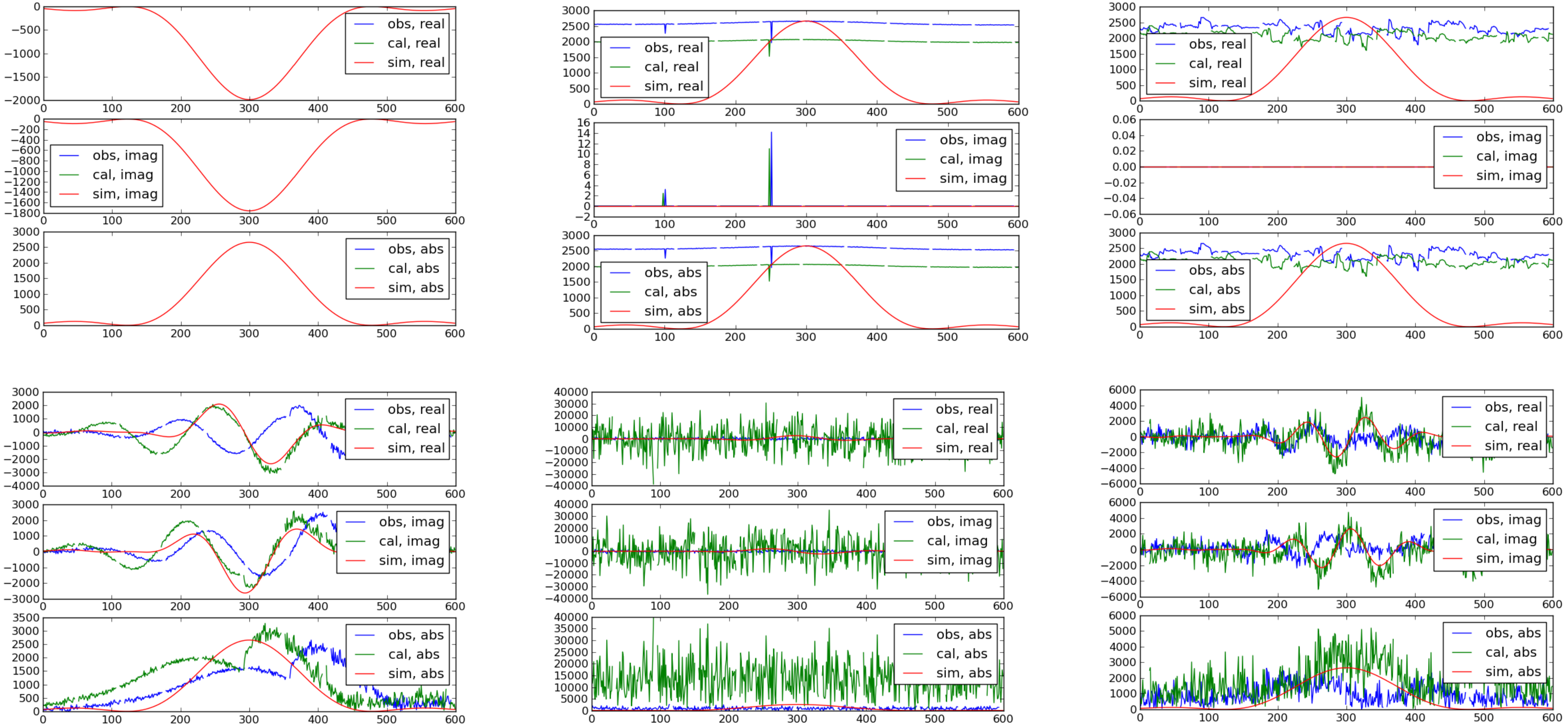
Calibration by Strong Point Source --- Cas A

By minimizing $\chi^2 = \|V^{\mathrm{obs}}(t+\Delta t) - G \cdot V^{\mathrm{sim}}(t)\|^2 \Longrightarrow G = \frac{V^{\mathrm{sim}\dagger} V^{\mathrm{obs}}}{V^{\mathrm{sim}\dagger} V^{\mathrm{sim}}}$

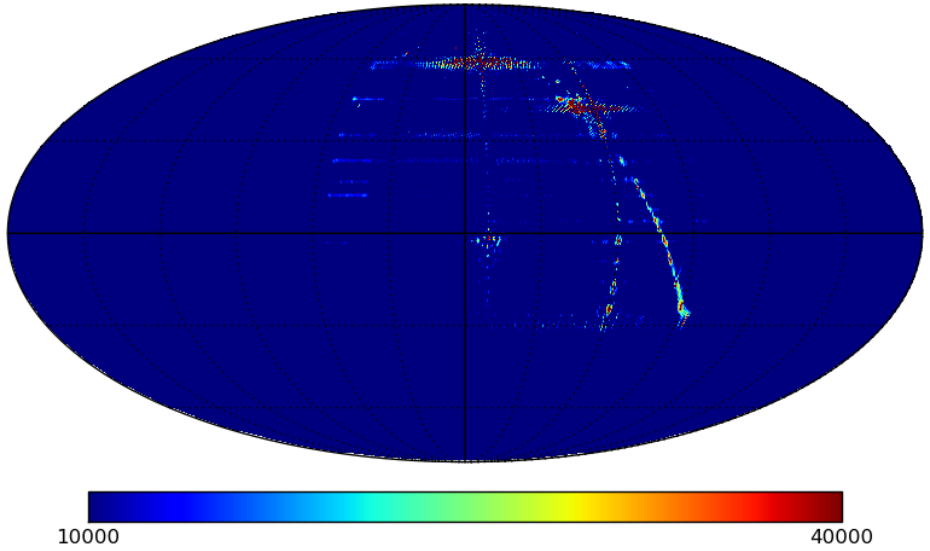


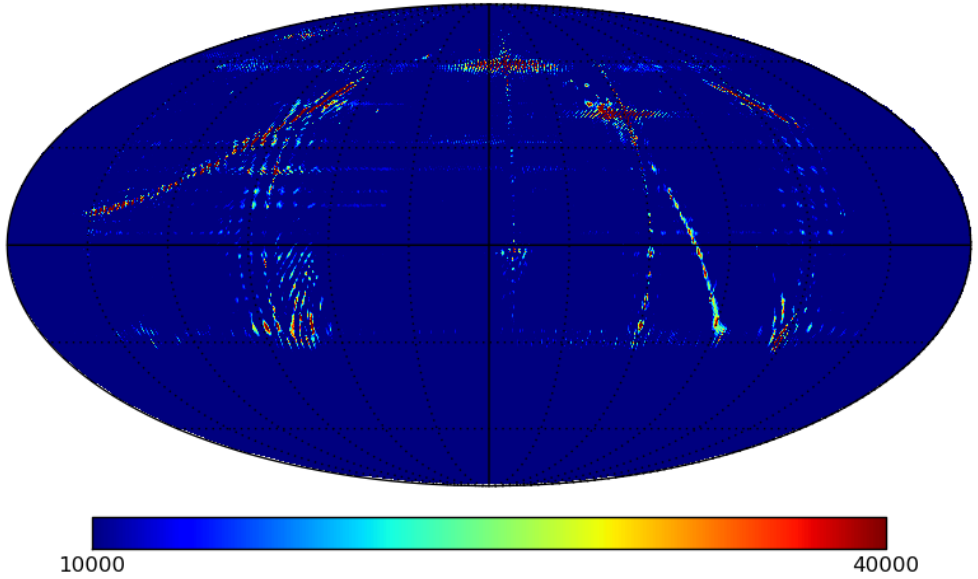
Bad/Exceptional Feeds

Include 3, 20, 28, 41, 50, 52, 77, 79, 57-68

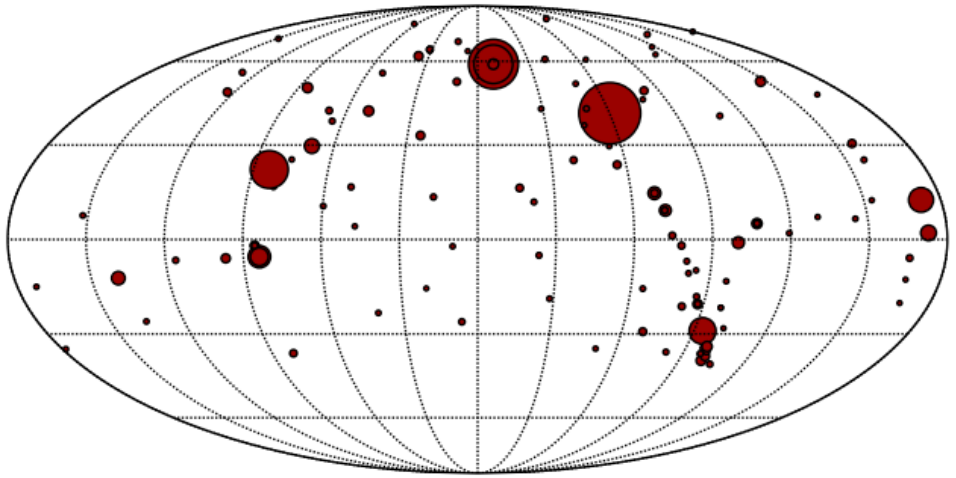


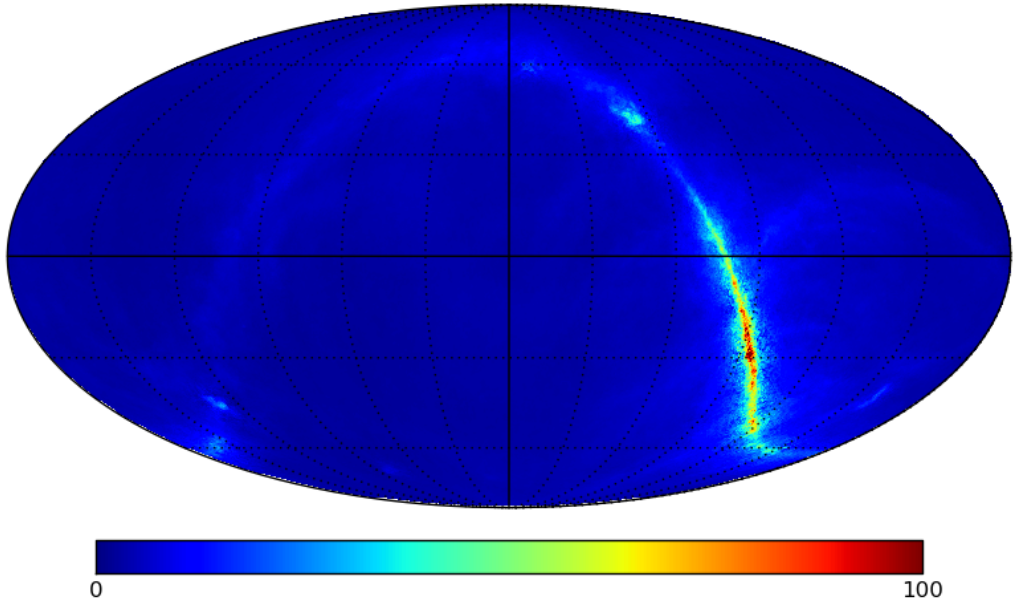
Map-Making





NVSS sources > 5Jy at 1.4 GHz



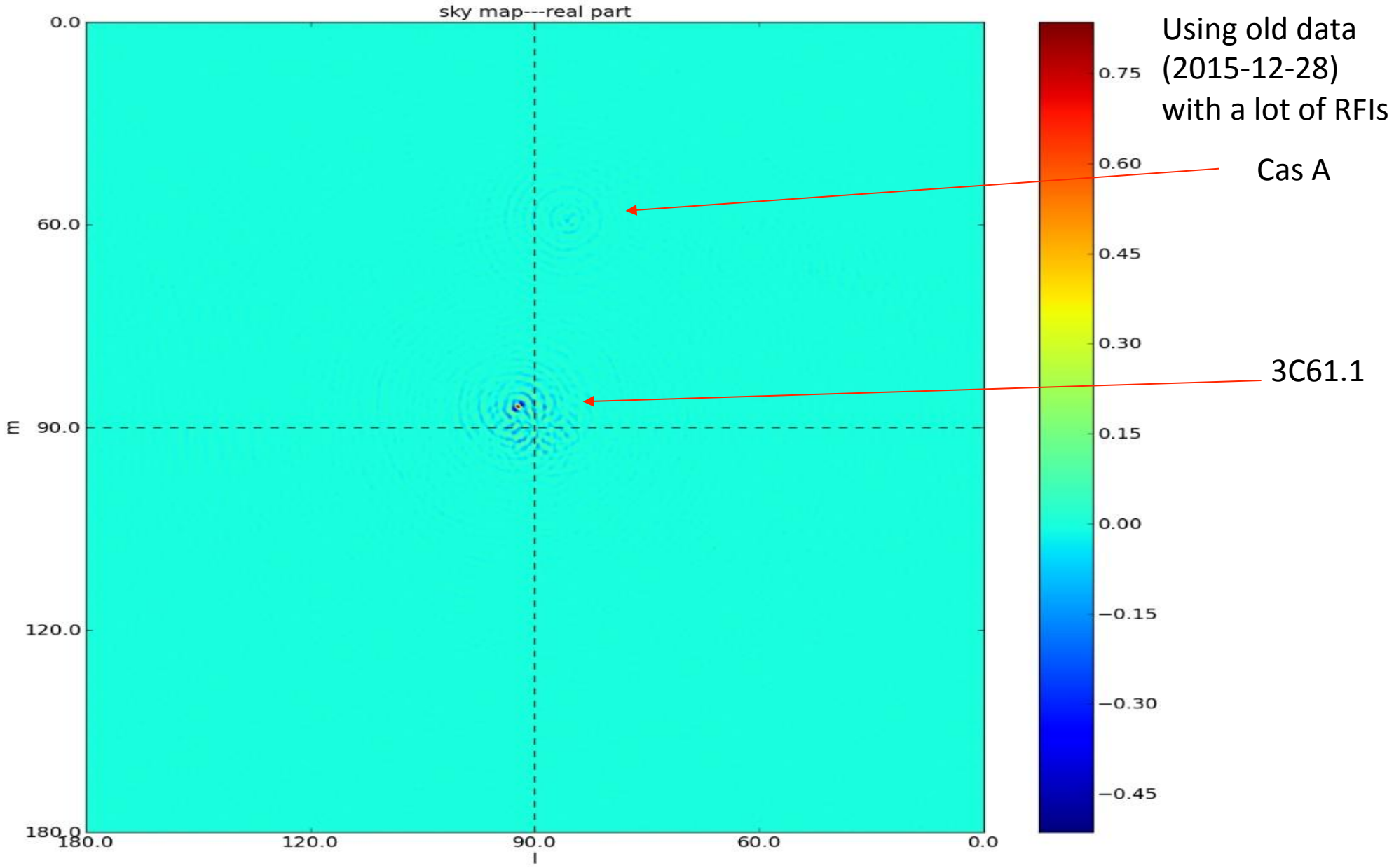


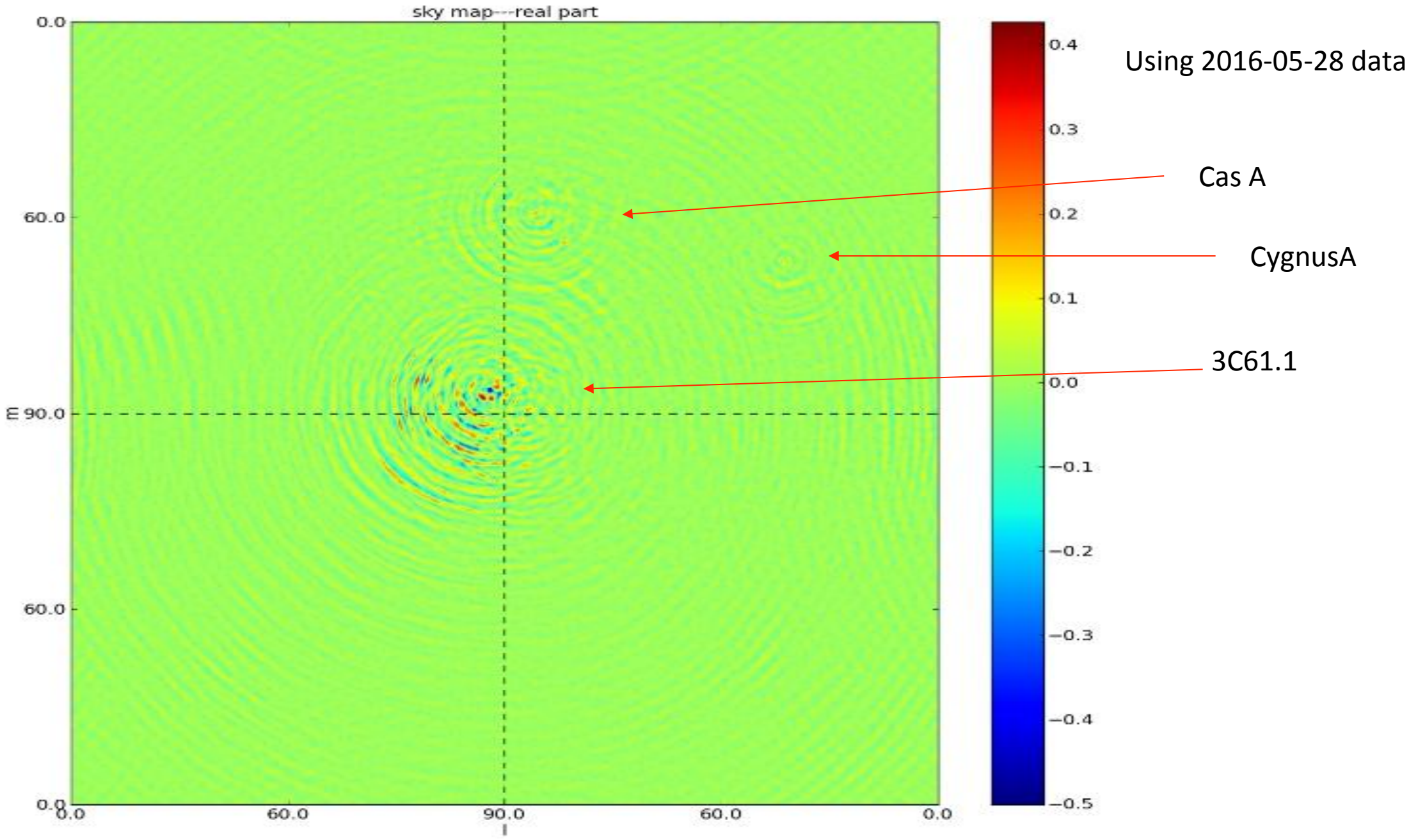
The Milk Way

Dish Array (Fengquan Wu & Qizhi Huang)

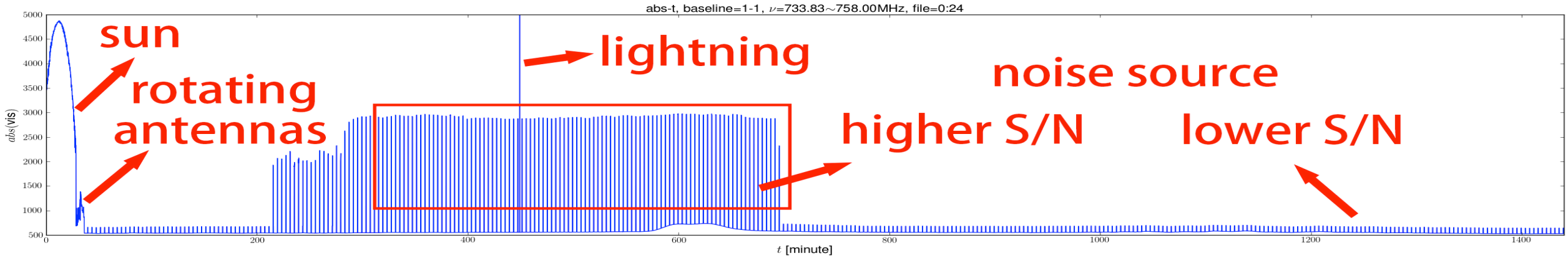
- Currently pointed North Pole
- Use a 32-channel correlator

Imaging of north celestial pole




sky map---real part
0.0
60.0
90.0
60.0
0.0
m
0.0
60.0
90.0
60.0
0.0
l
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
Using 2016-05-28 data
Cas A
CygnusA
3C61.1

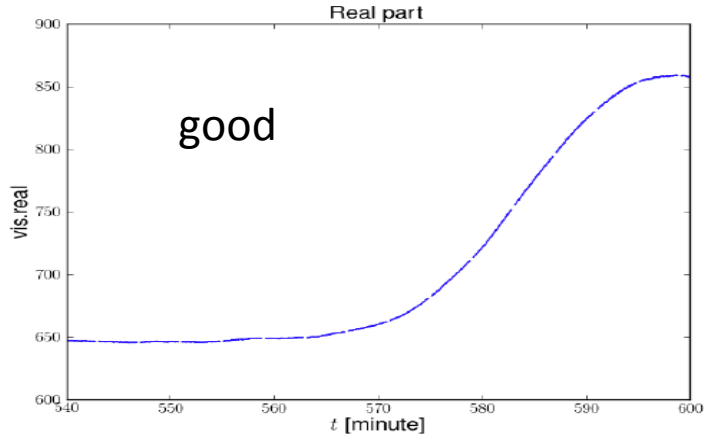
One day (24 hours) data

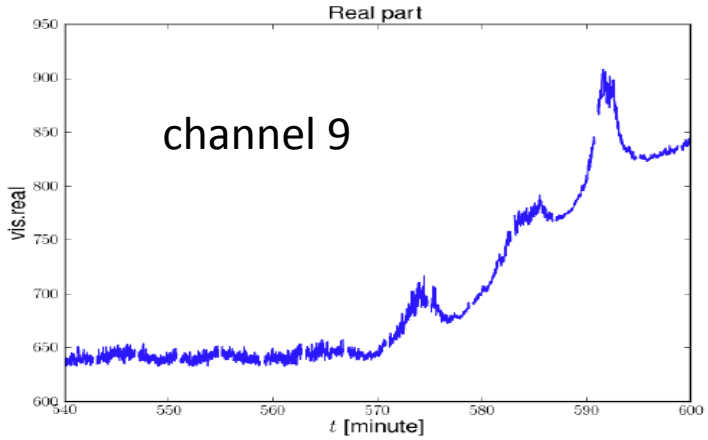


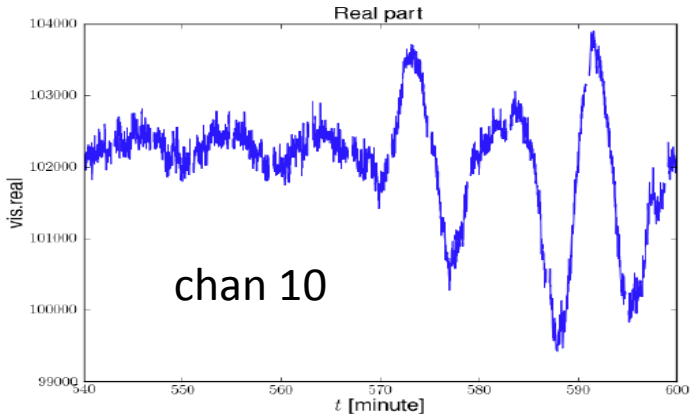
Select channels

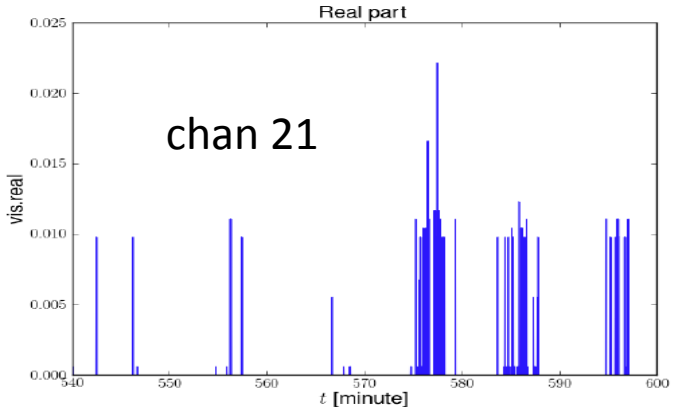
good channels 1, 2, 3, 4, 5, 6, 7, 8,
11, 12, 13, 14, 15, 16, 17, 18,
19, 20, 22, 25, 26, 28, 29,30, 31, 32

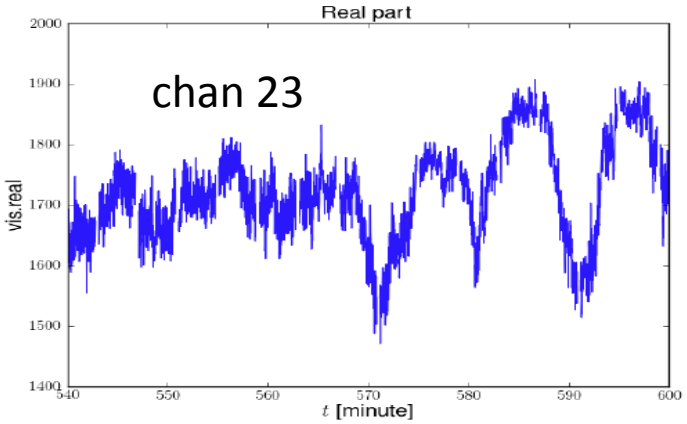
Bad channels: 9, 10, 21, 23, 24, 27

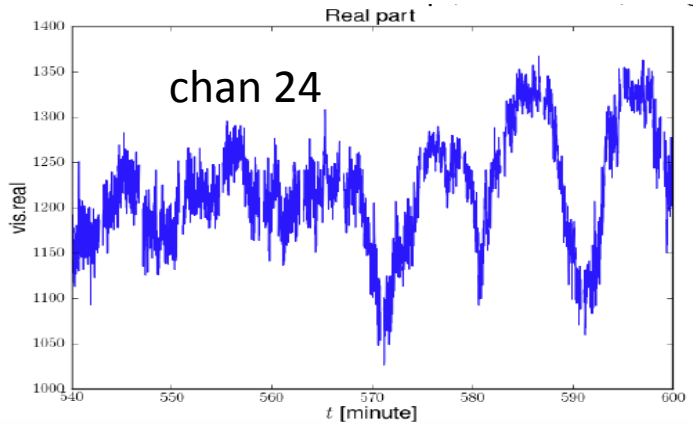


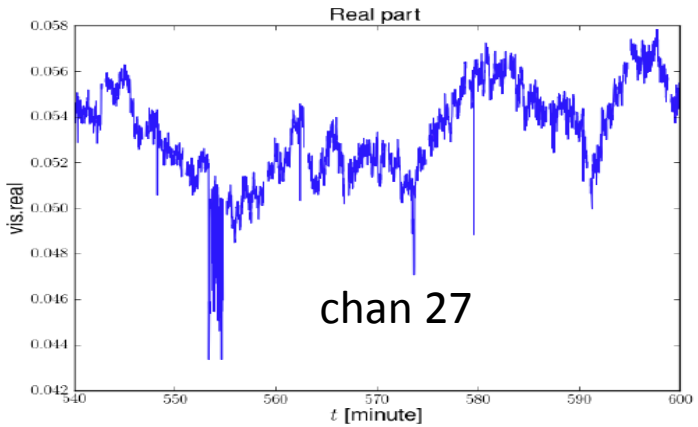










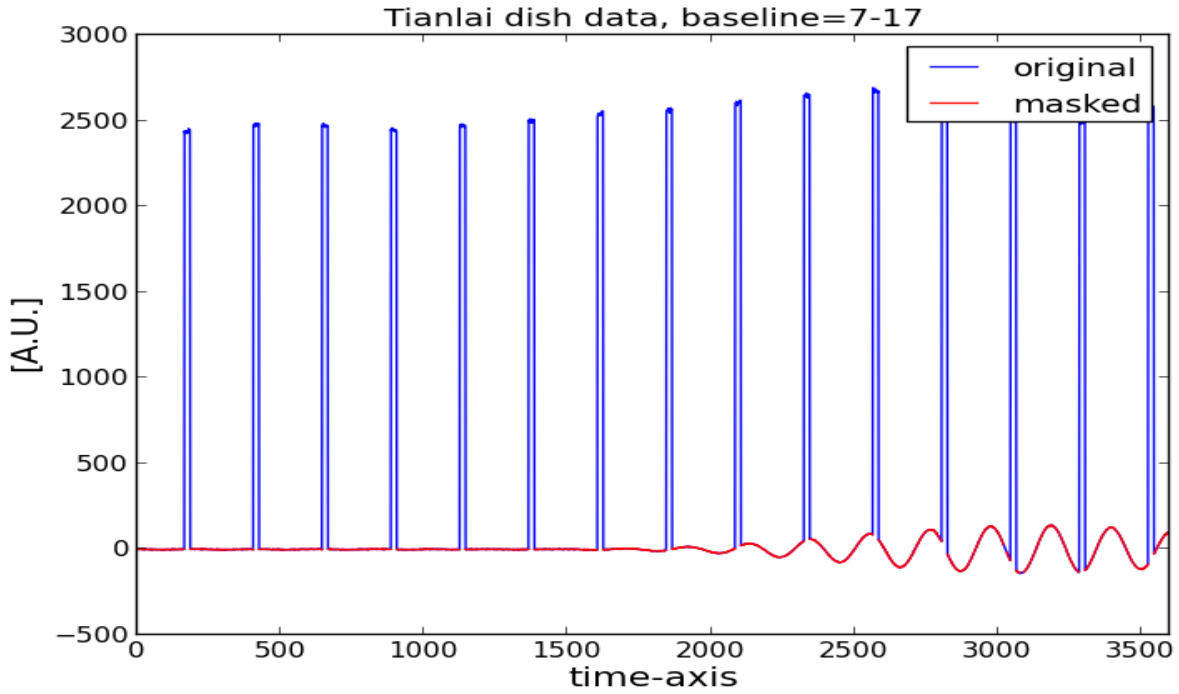


Masking RFI

(1)Mask noise source

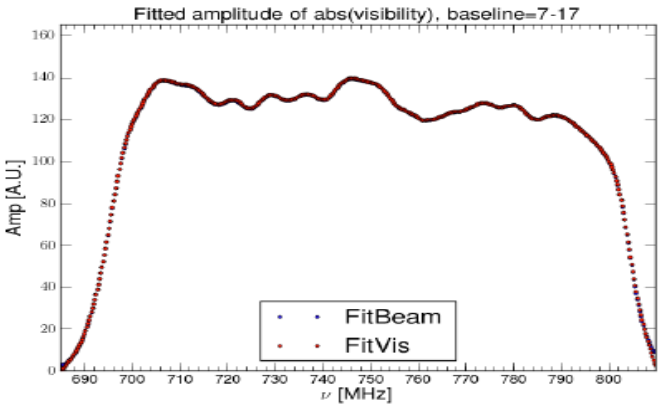
(2)Mask RFI with >3sigma => few masked points => less RFI

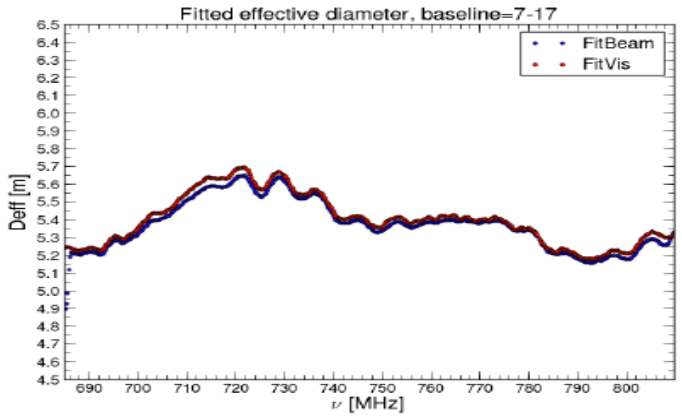
=> good radio environment



Fit fringe

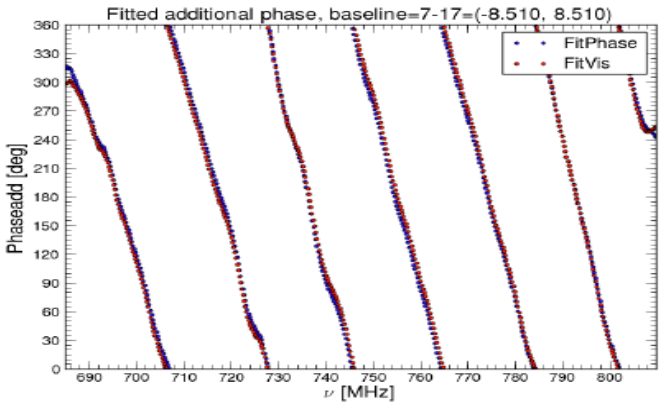
Frequency response





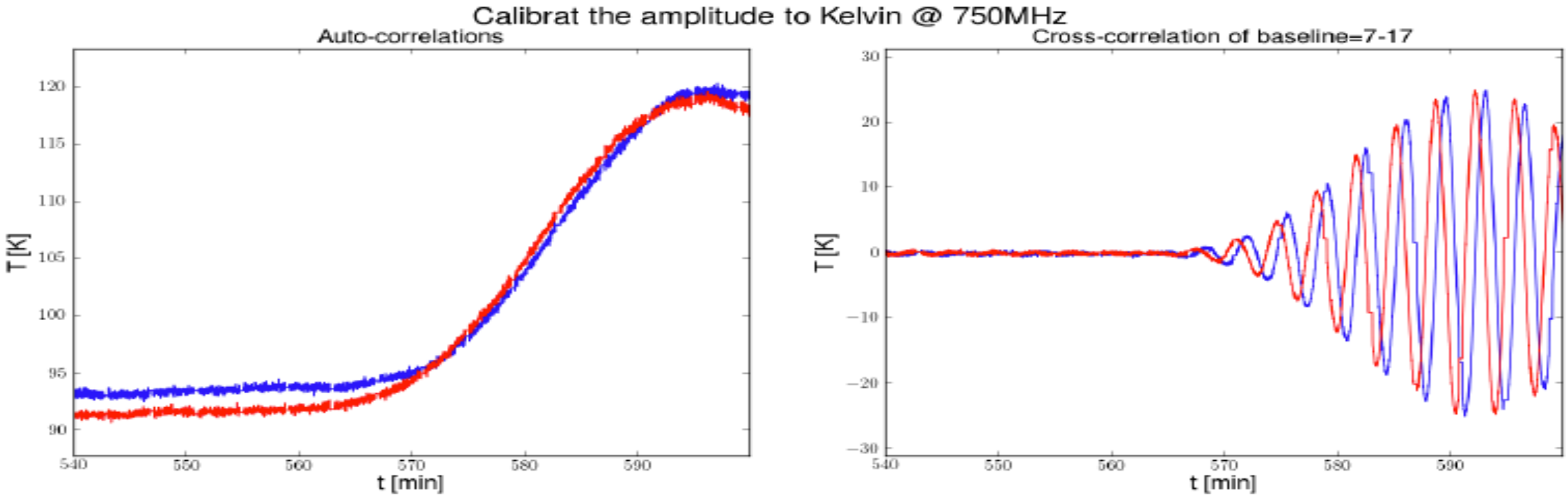
Effective diameter: 5.4 m
Physical diameter: 6 m
Aperture efficiency: 81%

The additional phase is proportional to frequency



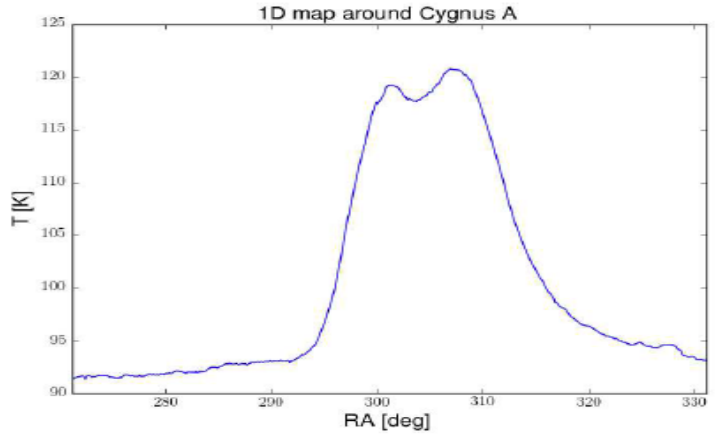
Calibrate the amplitude

Use Cygnus A to calibrate

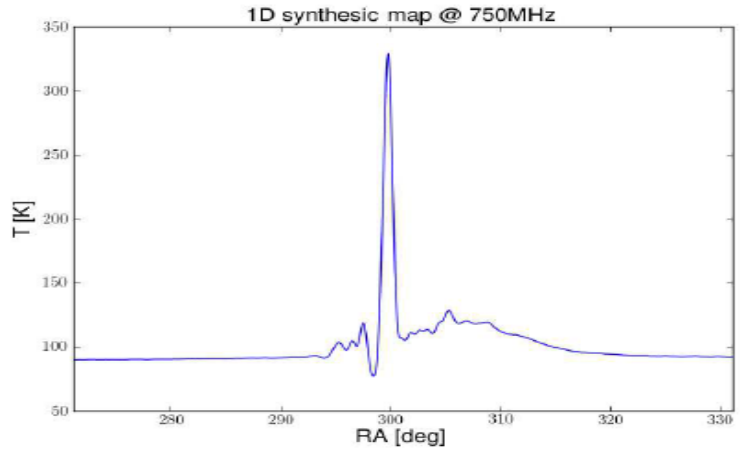


Synthesis map

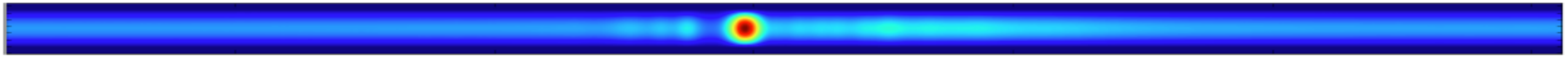
Cygnus A in single dish (6m)

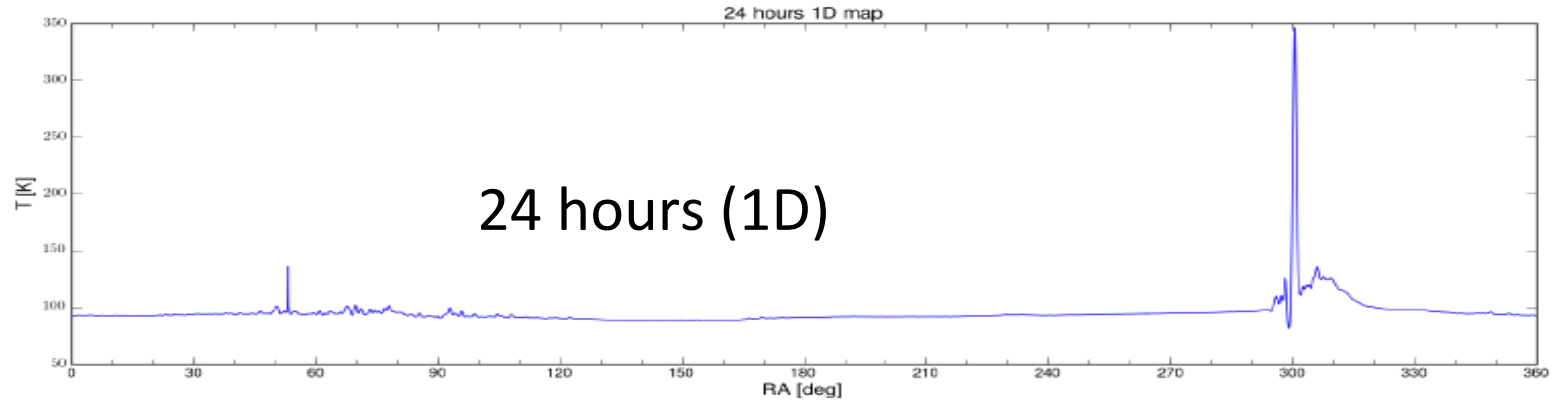


Synthesis map of Cygnus A with Tianlai dish array



Around Cygnus A





24 hours (1D)

Thank you!