Map-making with the Tianlai Cylinder Array

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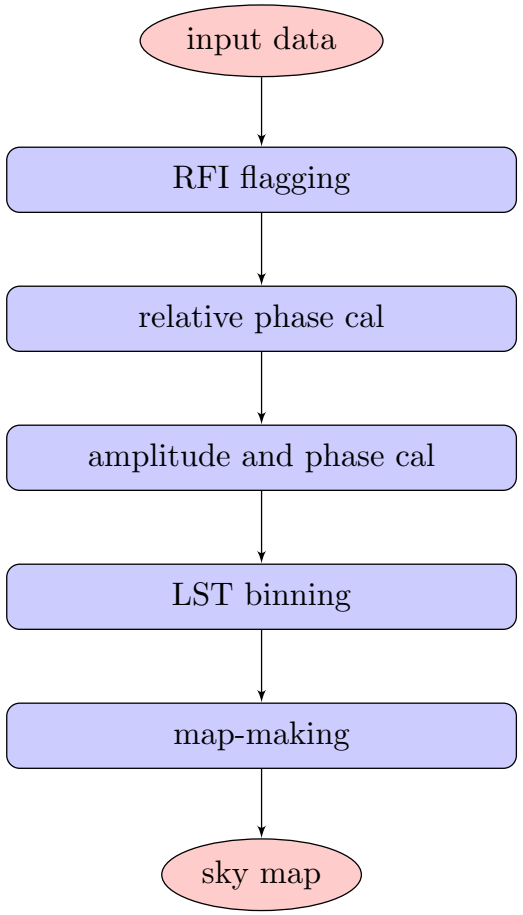
Data

- Two datasets observed by the cylinder pathfinder:

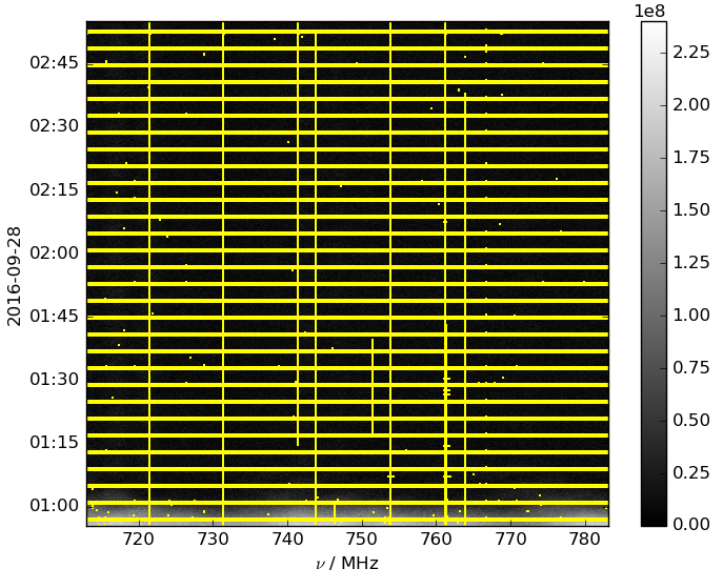
  (1) one observed during September 27, 2016 to October 1, 2016, including 5 days data

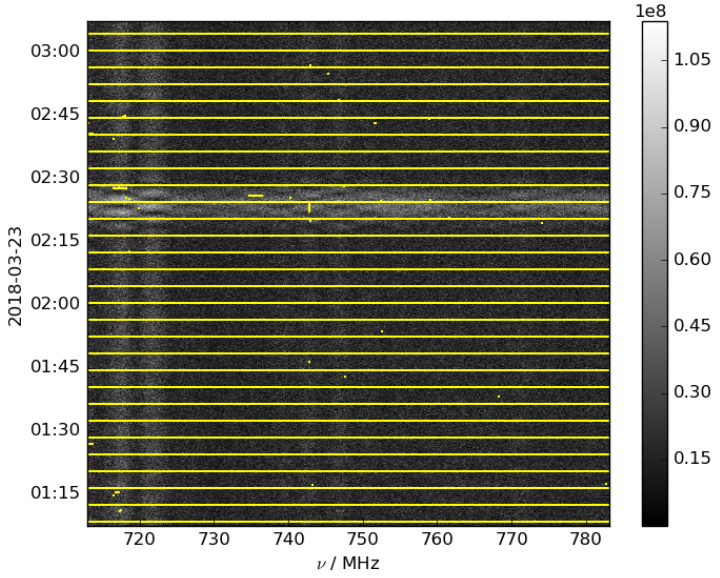
  (2) another observed during March 22, 2018 to March 28, including 6 days data
- Complement to each other to maximumly eliminate the effects of the Sun contamination.
- 576 available frequency points, between 710 MHz – 780 MHz.
- Use *tlpipe* (https://github.com/TianlaiProject/tlpipe) for data reduction.

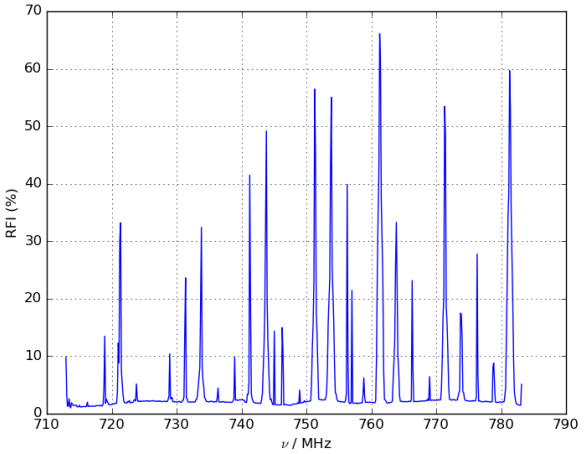
Data Processing Flow

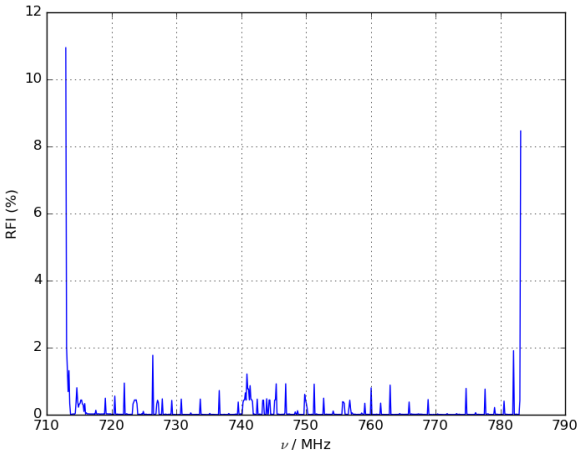


RFI Flagging







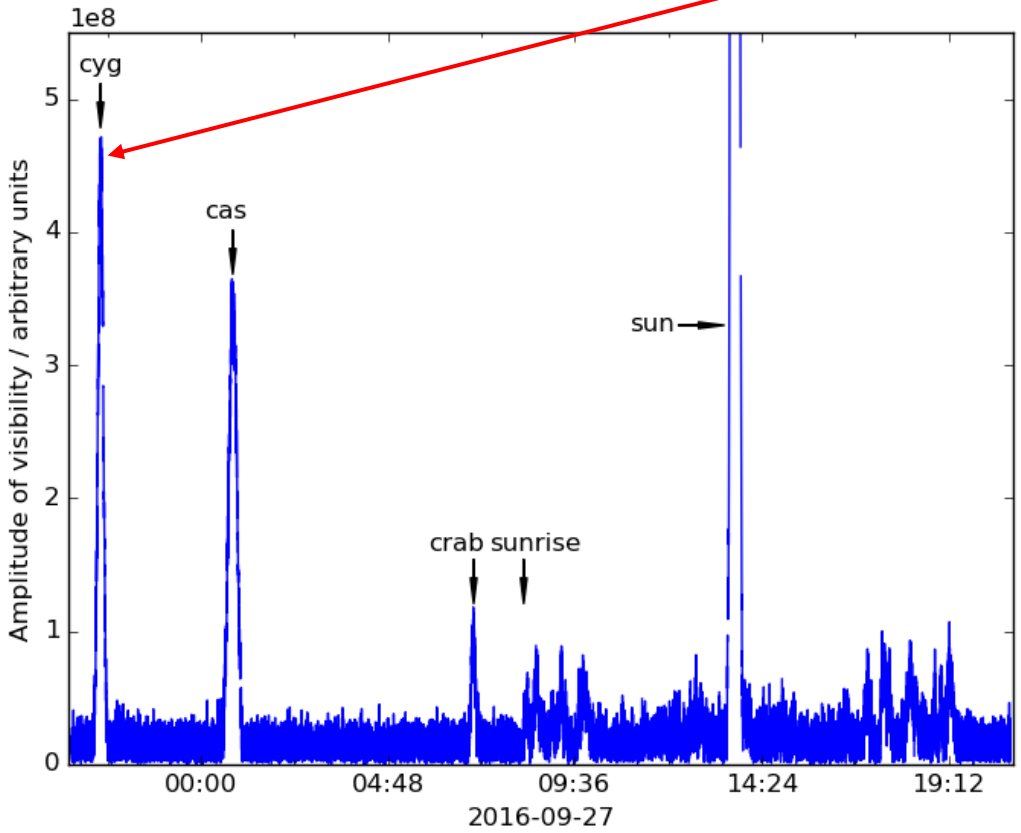


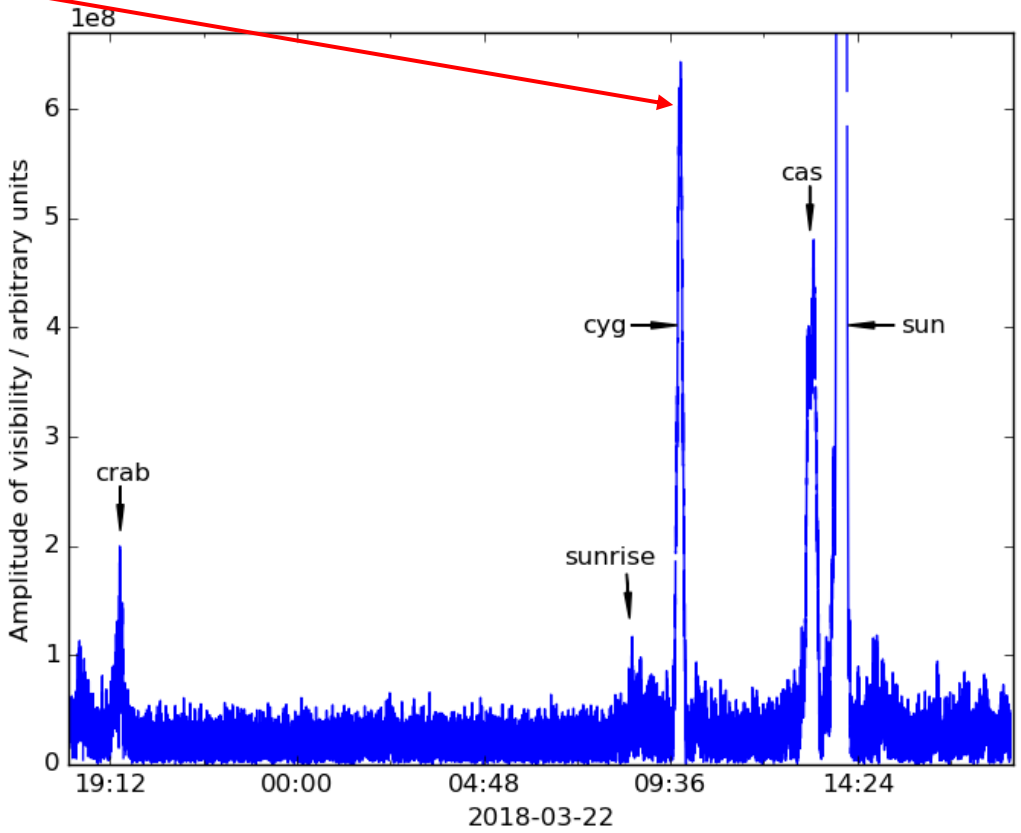
September 2016

March 2018

Visibility

Use Cygnus A as calibrator.





September 2016

March 2018

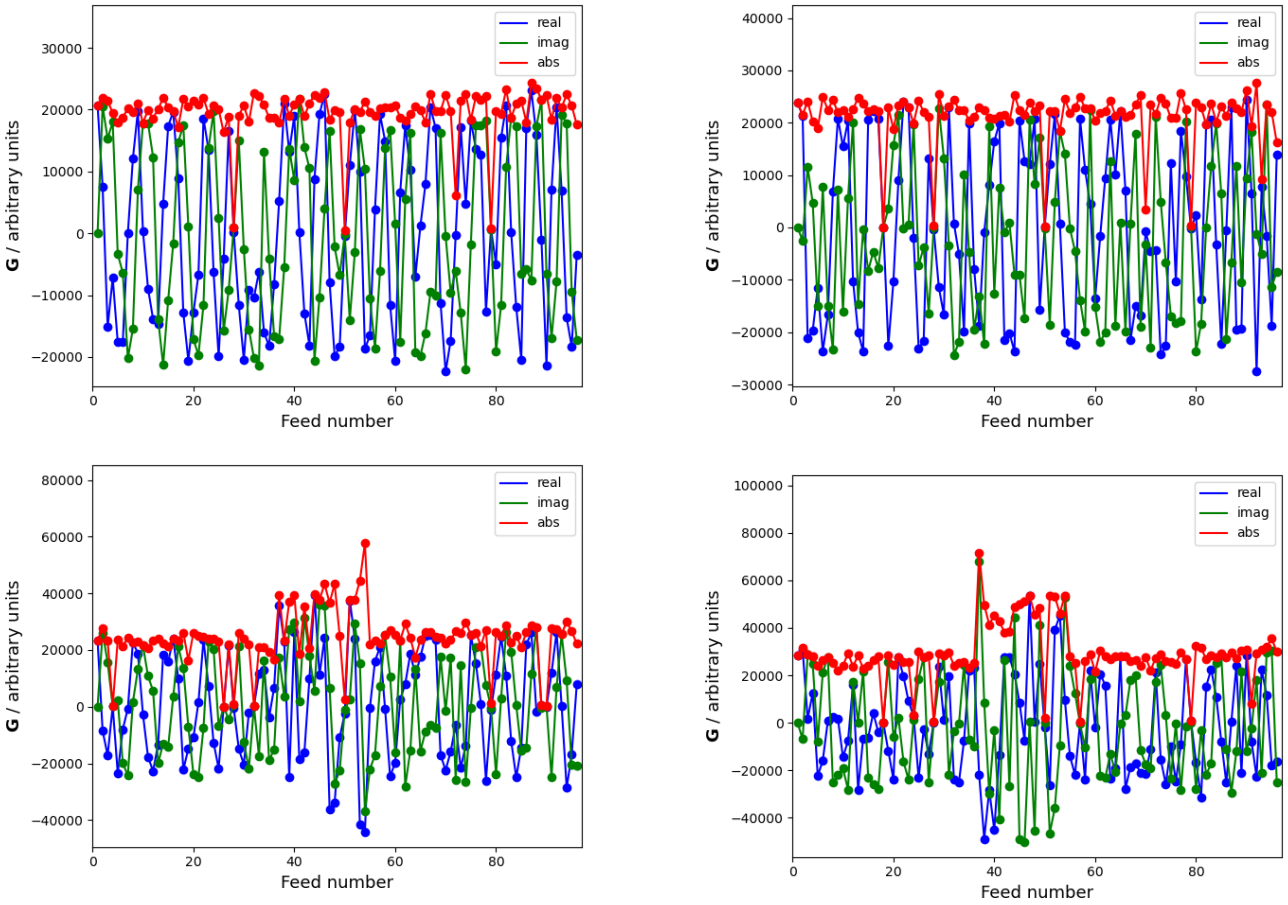
Calibration

- Use the eigen-vector based calibration method

$$\boldsymbol{V}_0 = S_c \boldsymbol{G}\boldsymbol{G}^\dagger, \qquad \text{where} \qquad G_i = g_i A_i(\hat{\boldsymbol{n}}_0) e^{-2\pi i \hat{\boldsymbol{n}}_0 \cdot \boldsymbol{u}_i}.$$

September 2016

March 2018



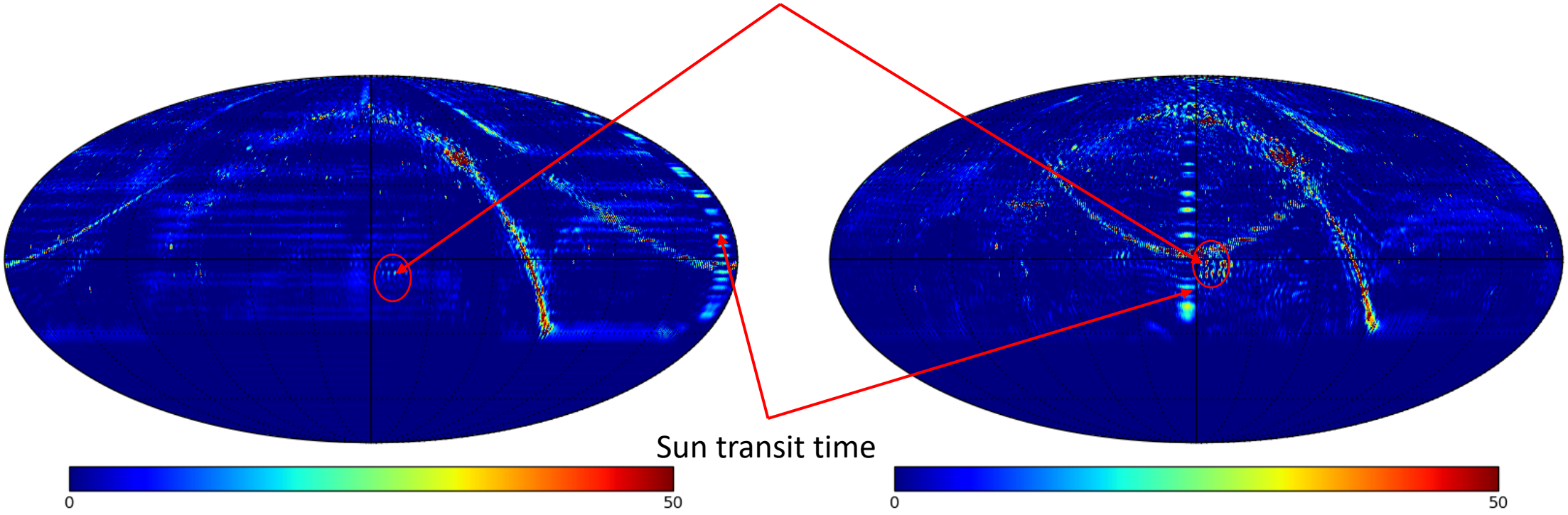
XX YY

Map-Making

Using m-mode map-making method $\boldsymbol{v} = \boldsymbol{B}\,\boldsymbol{a} + \boldsymbol{n}.$

Tikhonov regularization-based solver $\hat{\boldsymbol{a}} = (\boldsymbol{B}^*\boldsymbol{B} + \varepsilon \boldsymbol{I})^{-1}\boldsymbol{B}^*\boldsymbol{v}, \quad \varepsilon = 0.0001$

Unknown interference

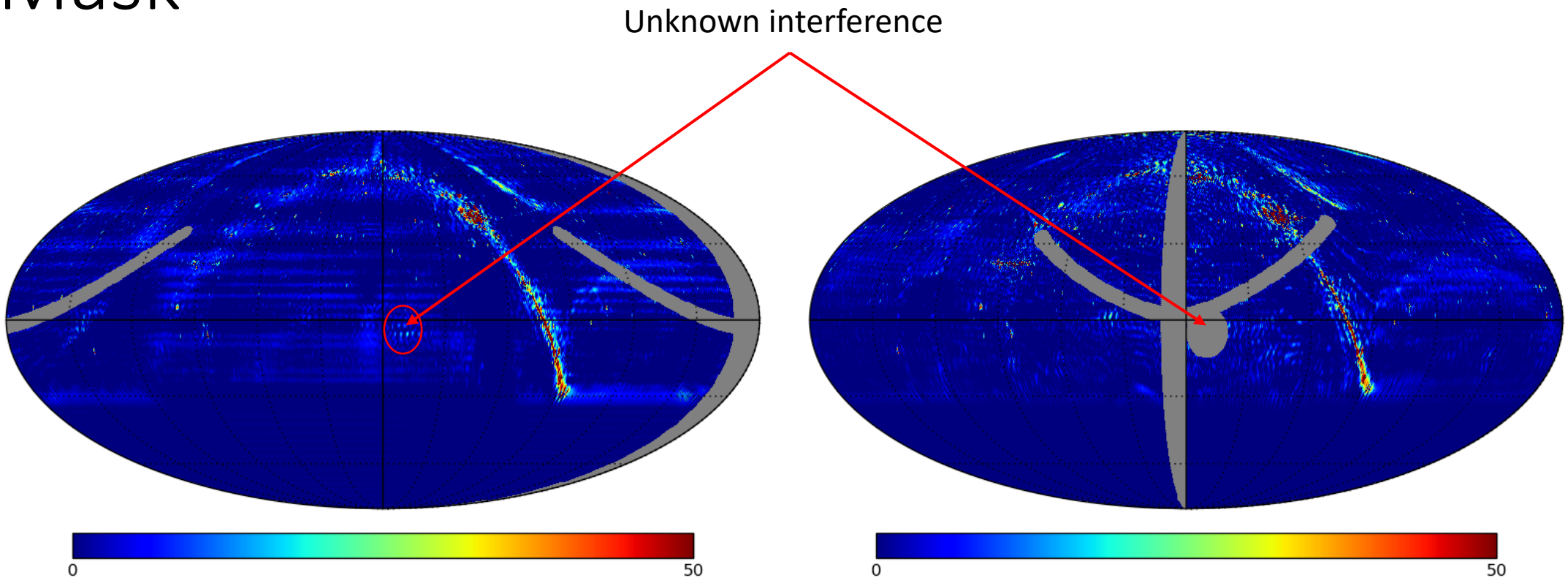


Sun transit time

September 2016

March 2018

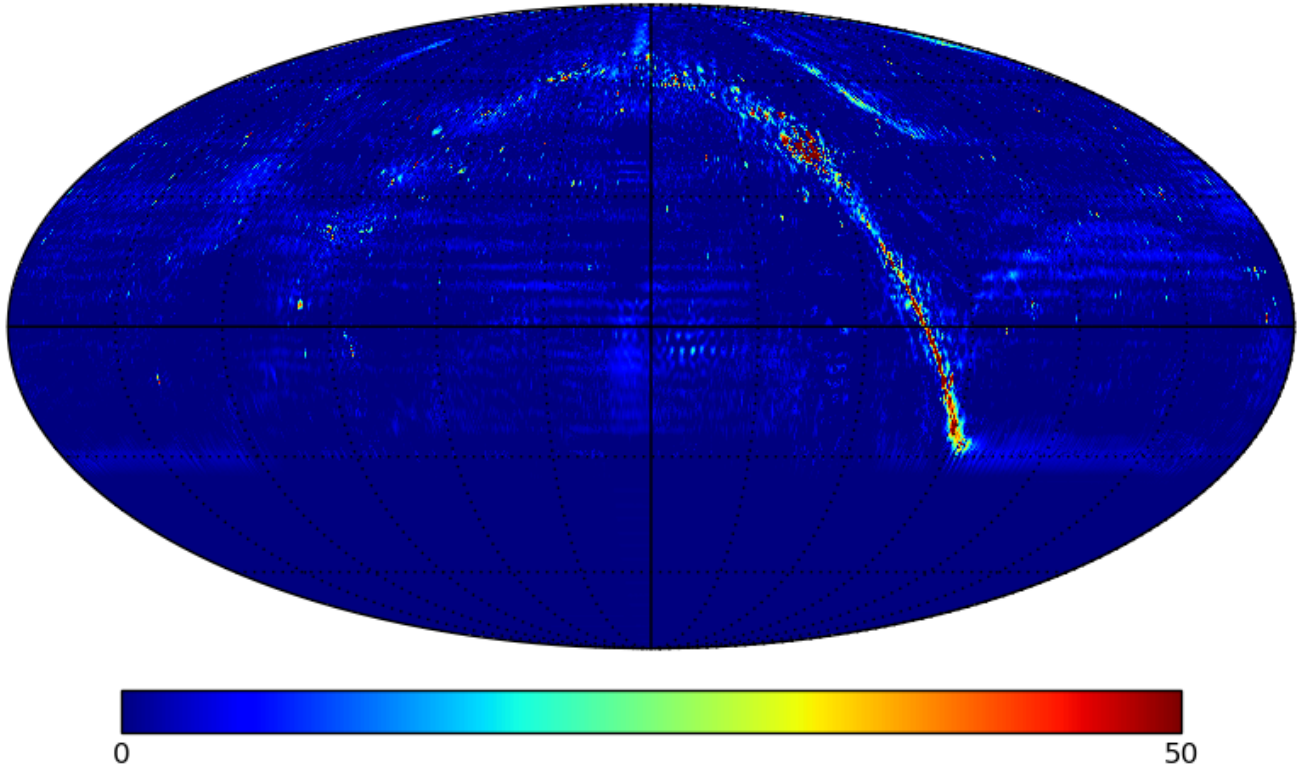
Mask



September 2016

March 2018

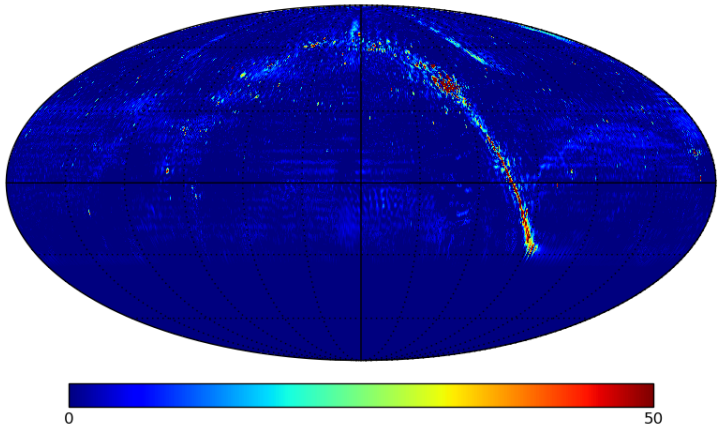
Synthesized Map



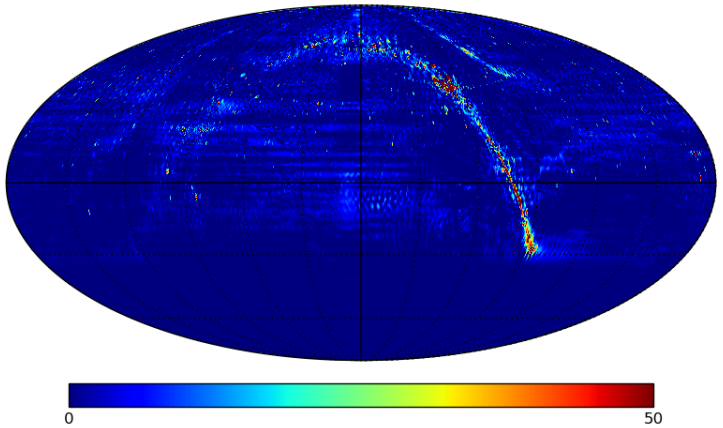
750 MHz

Made Maps

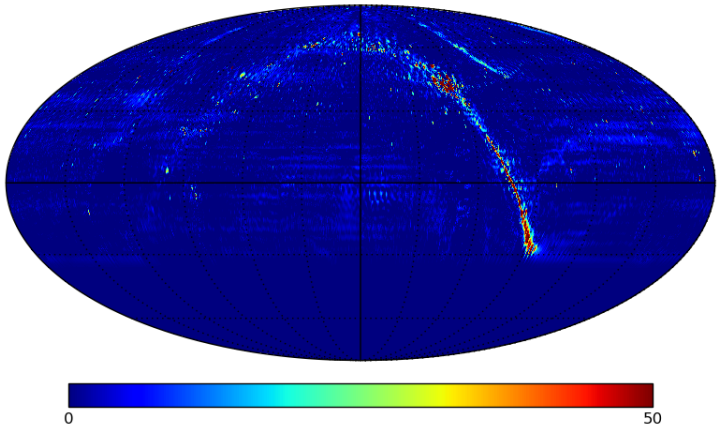
Map made by binning 4 adjacent frequency points.
Finally got maps of 144 frequency points between 710 MHz – 780 MHz.



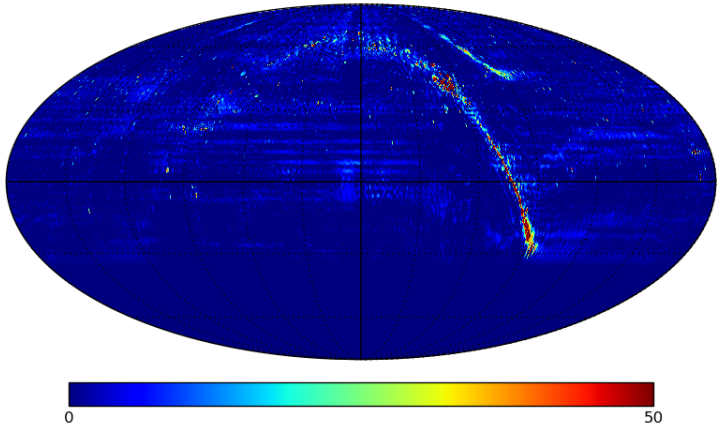
720 MHz



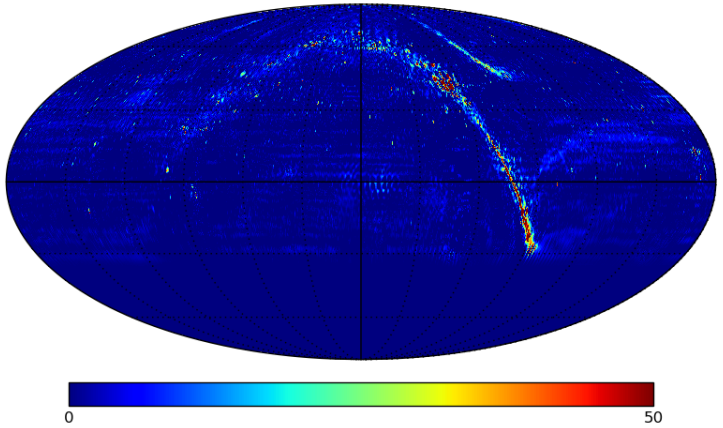
730 MHz



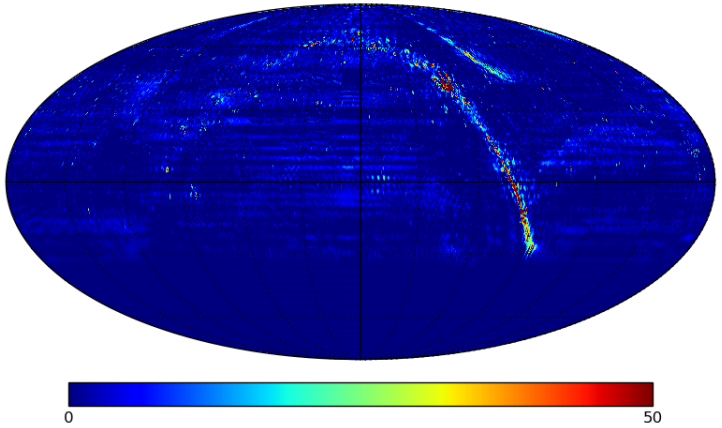
740 MHz



760 MHz

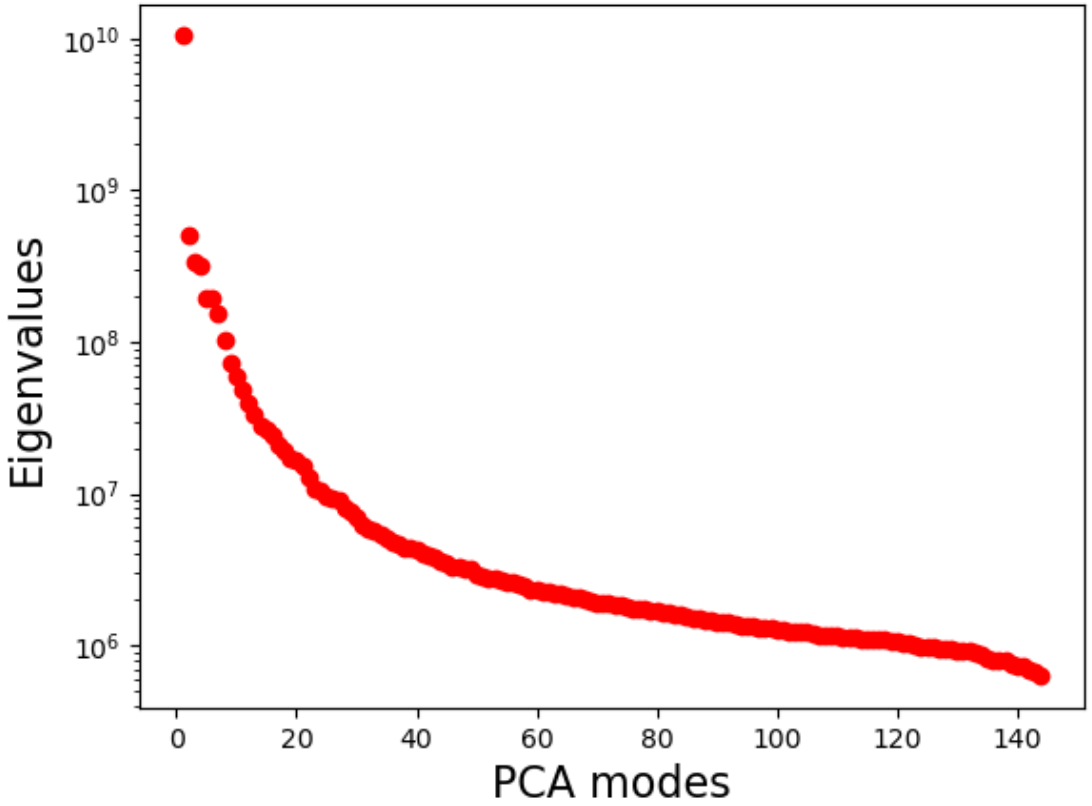


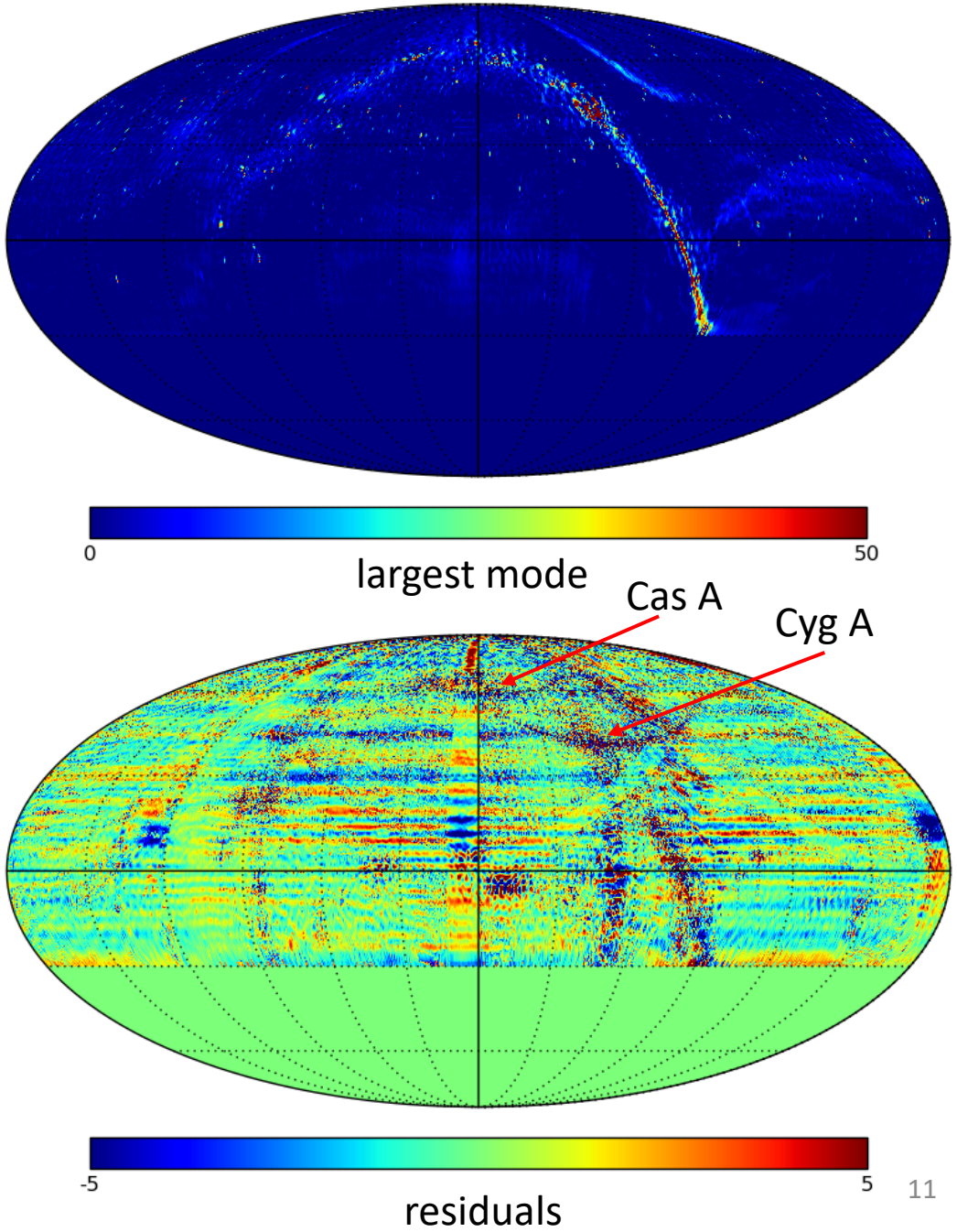
770 MHz



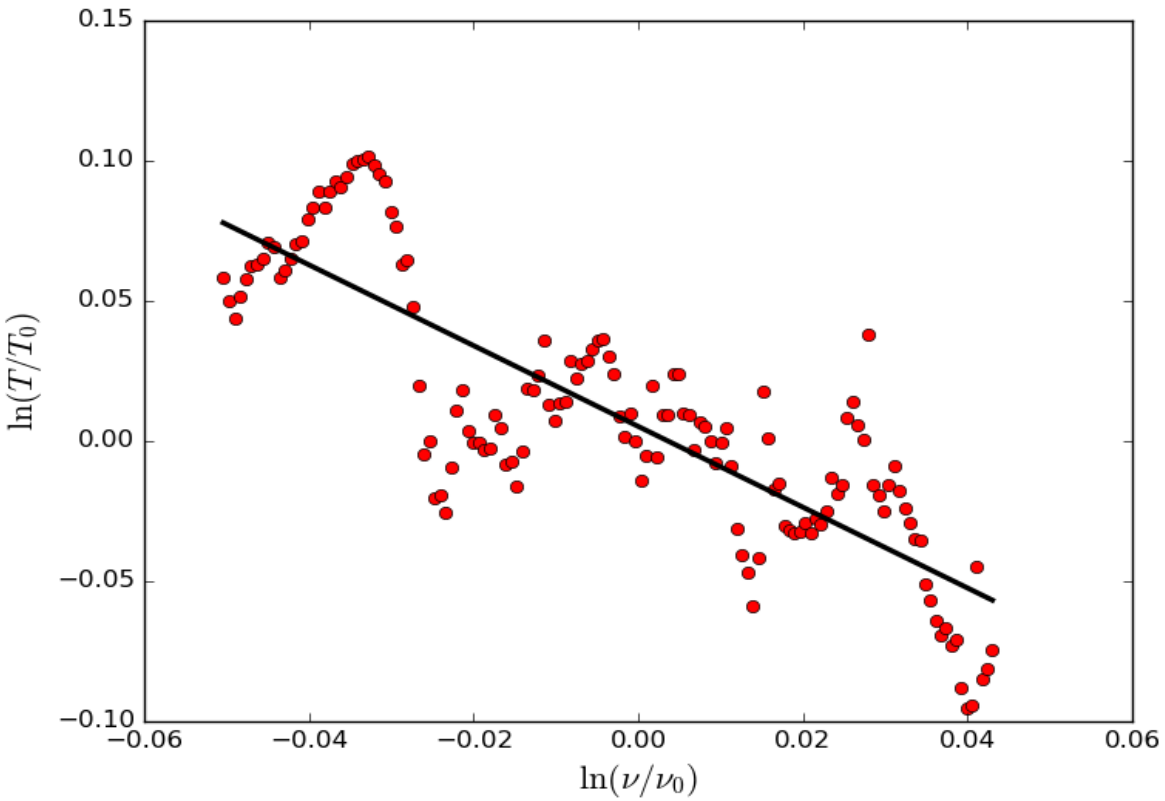
780 MHz

PCA Analysis





Frequency Spectrum of the Largest PCA Mode

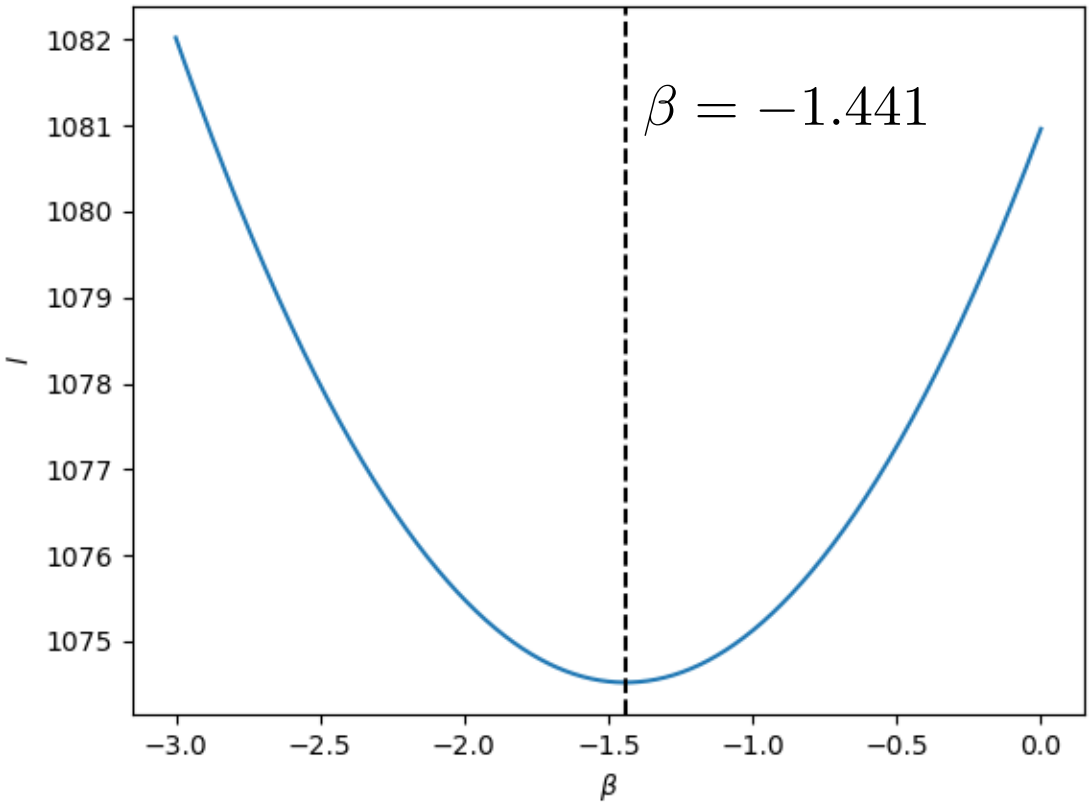


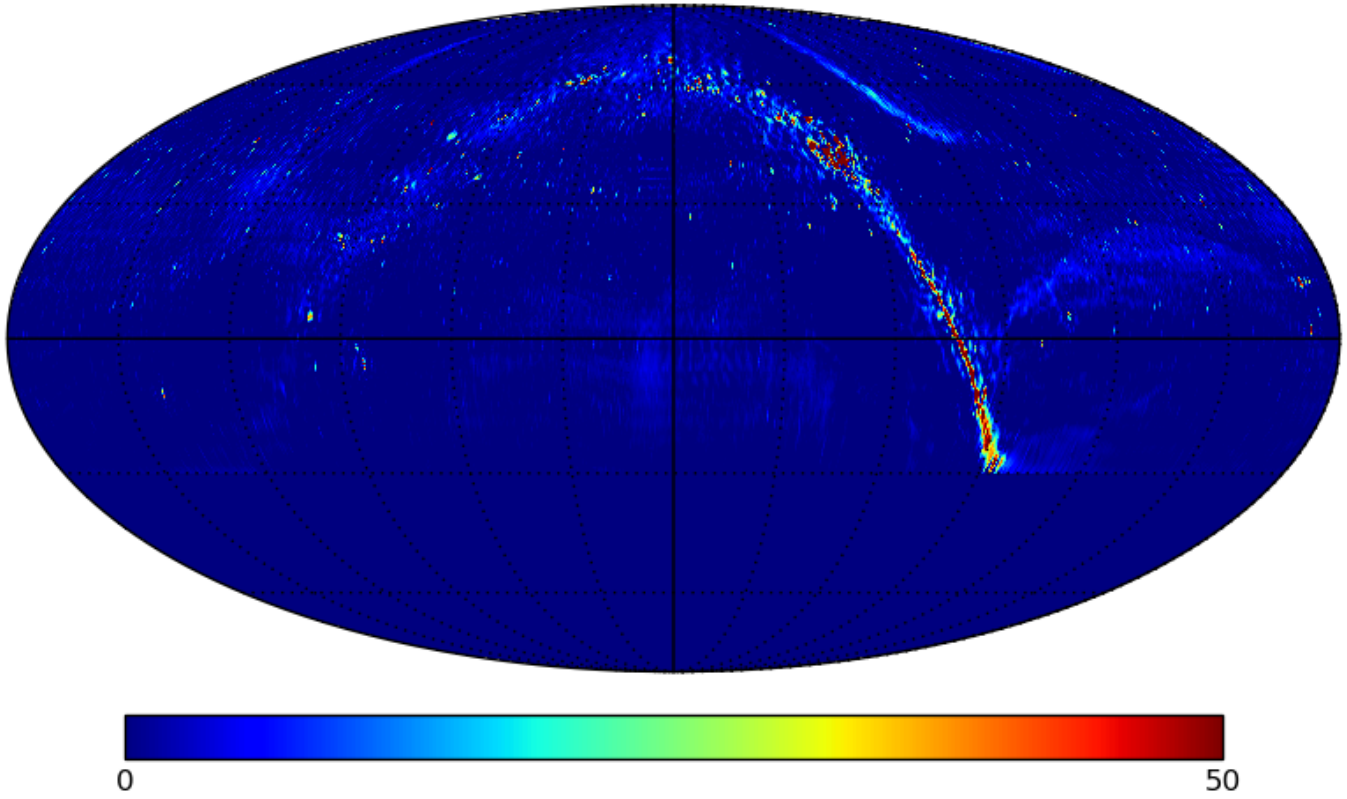
$$T(\nu) = T_0(\frac{\nu}{\nu_0})^{\beta},$$

where ν_0 = 750 MHz and T_0 is the brightness temperature at ν_0.
The slope of the fitted line give the spectral index $\beta = -1.441$.

Multi-frequency Fitting

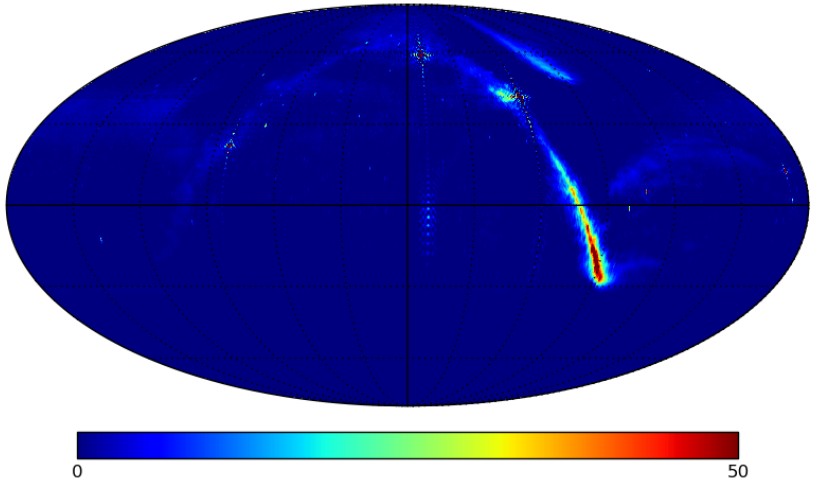
minimize $$l = \sum_{i=1}^{N_{\mathrm{freq}}} \left\| m_i - m_c \left(\frac{\nu_i}{\nu_c}\right)^{\beta} \right\|_2^2 \longrightarrow m_c = \frac{\sum_{i=1}^{N_{\mathrm{freq}}} m_i \left(\frac{\nu_i}{\nu_c}\right)^{\beta}}{\sum_{i=1}^{N_{\mathrm{freq}}} \left(\frac{\nu_i}{\nu_c}\right)^{2\beta}}$$



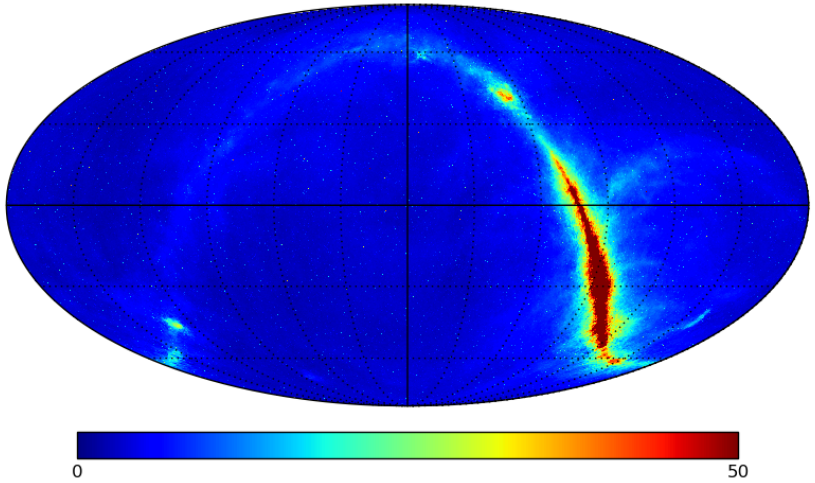


Map Deconvolution with Neural Network

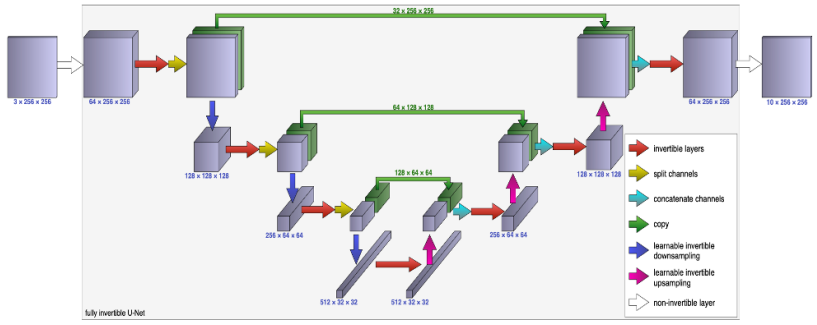
Train an iUNet (invertible U-Net) with simulated sky maps.



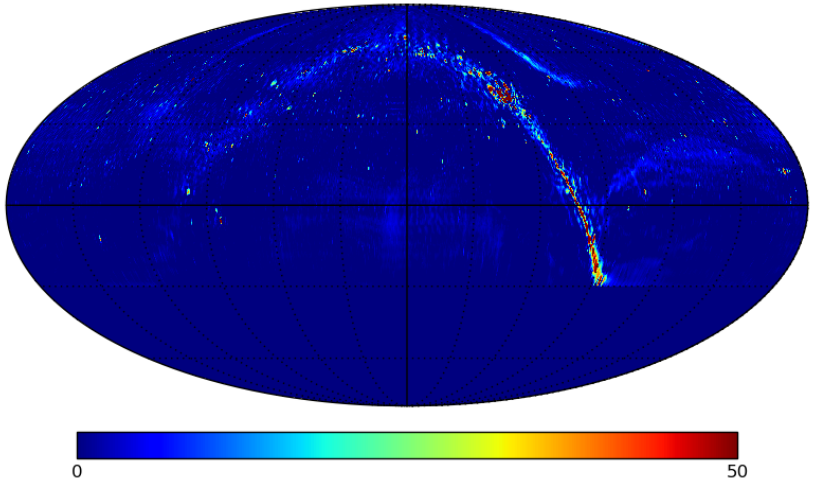
Simulated reconstruction



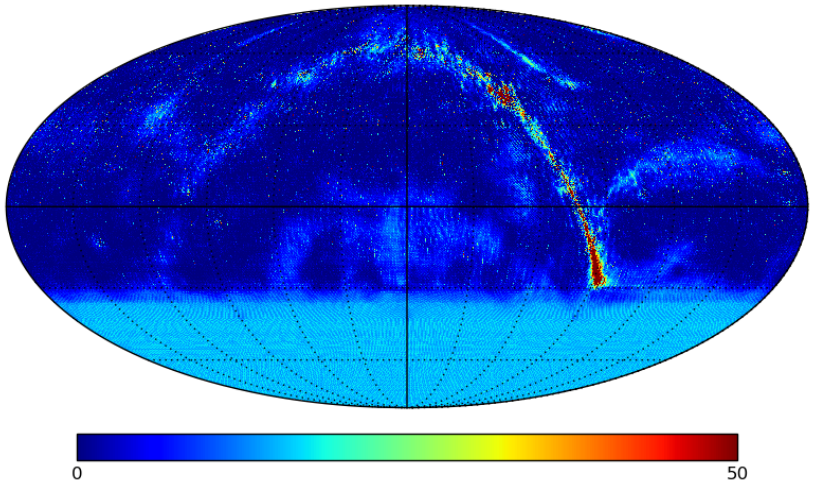
Simulated sky



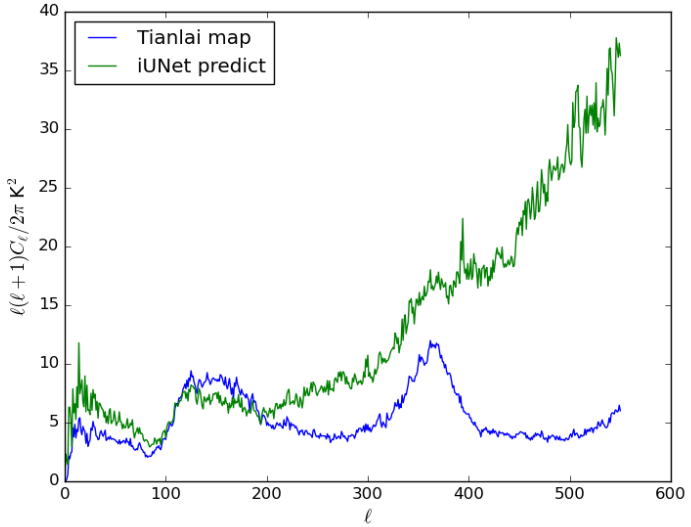
iUNet



Tianlai reconstruction



iUnet predict



Angular power spectrum

Future works

- Better RFI flagging and calibration.
- Beam response measurment and modeling.
- Build sky model for calibration.
- Reduct more data.
- Further analysis for the maps.
- …