TABASCAL

Trajectory Based RFI Subtraction and Calibration

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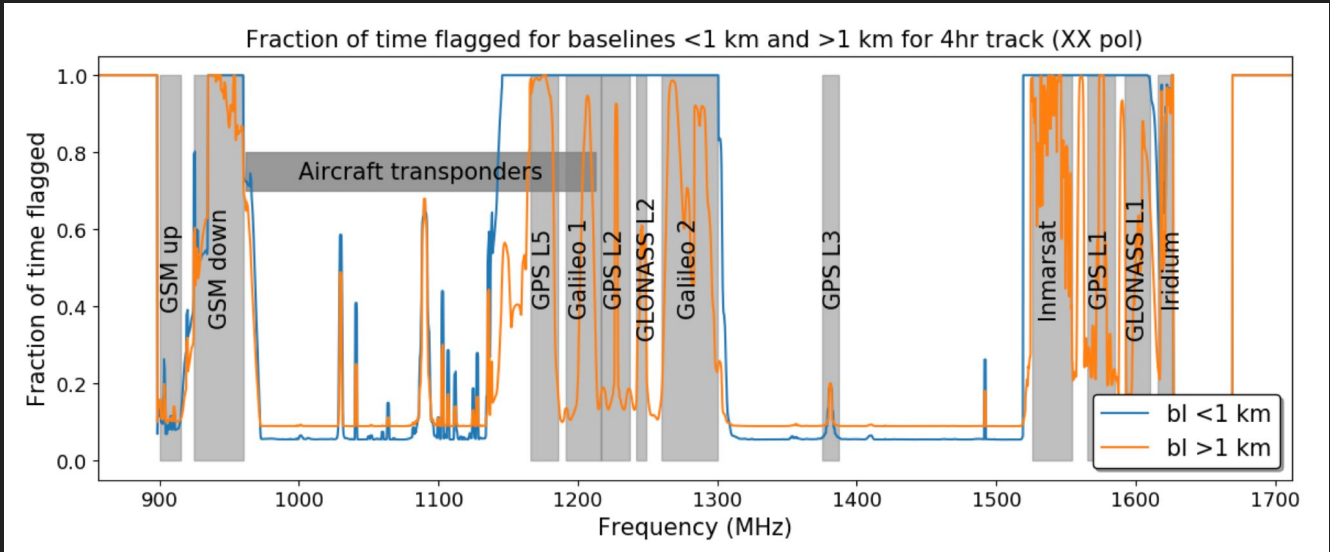
Radio Frequency Interference (RFI) - Motivation

- 30 % of the MeerKAT (SKA-Mid) L-band is contaminated.
- Much of it is (reasonably) predictable
- MeerKAT cost $ 330 M → $ 100 M is being wasted.



TABASCAL

Goals

- Replace flagging with RFI subtraction to recover astronomical visibilities.
- Fit into the current data reduction workflow - 1GC then 2GC (self-cal) and beyond.

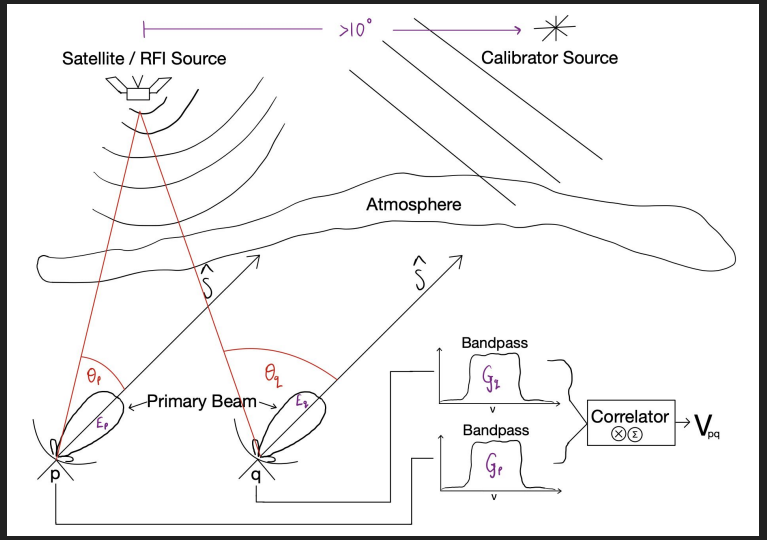
Ideas

- Use RFI trajectories to help estimate their visibility contribution.
- Estimate antenna gains by using prior information.
- Use baseline dependent smoothness of astronomical visibilities to help with estimation.

Data Simulations

Features

- Satellite and Ground-based RFI sources
- Correlator averaging (Fringe loss)
- Direction Independent Gains
- Realistic point source sky astronomical model
- Fast JAX implementation for CPU, GPU & TPU
- Scalable with Dask to multiple GPUs

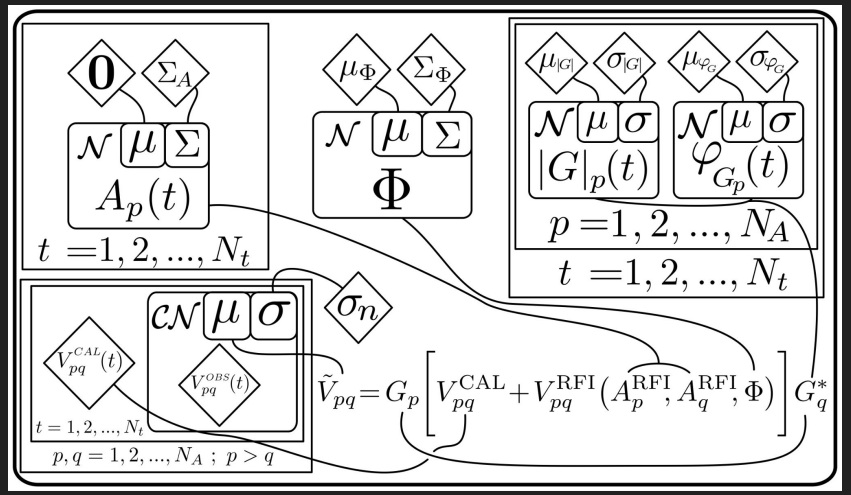


https://github.com/chrisfinlay/tabascal

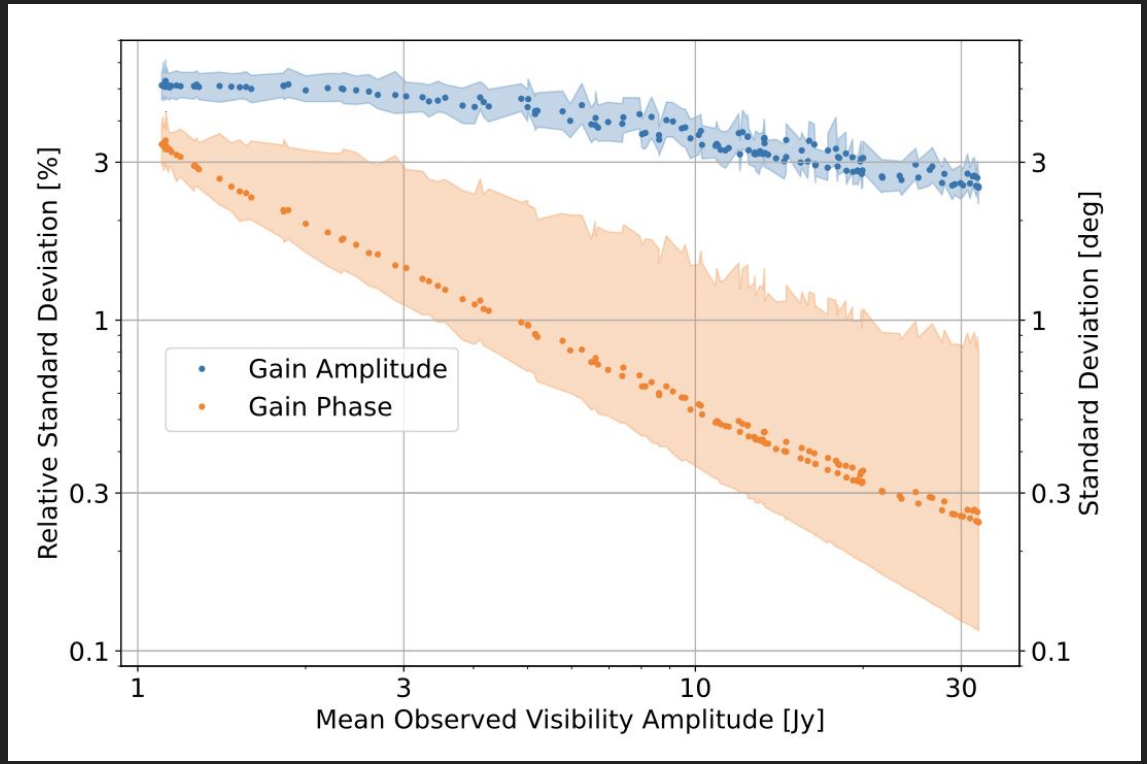
TABASCAL I (1GC)

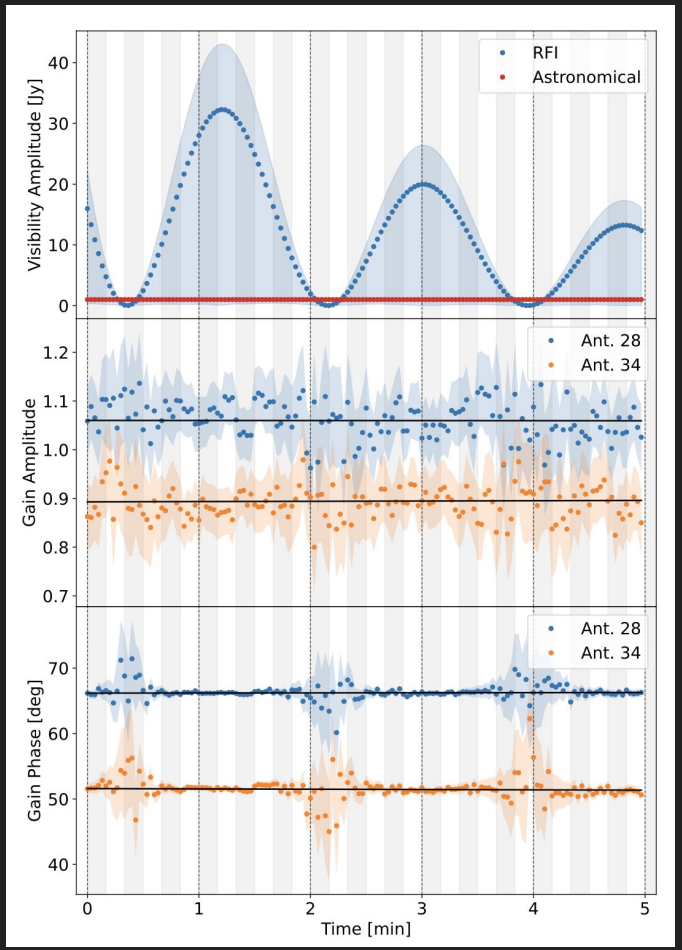
arXiv:2301.04188

- Jointly estimate RFI and antenna gains.
- Bayesian model to reliably estimate parameter errors.



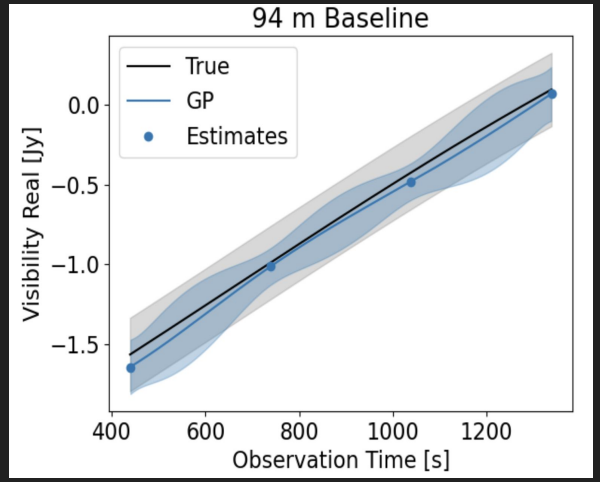
TABASCAL I

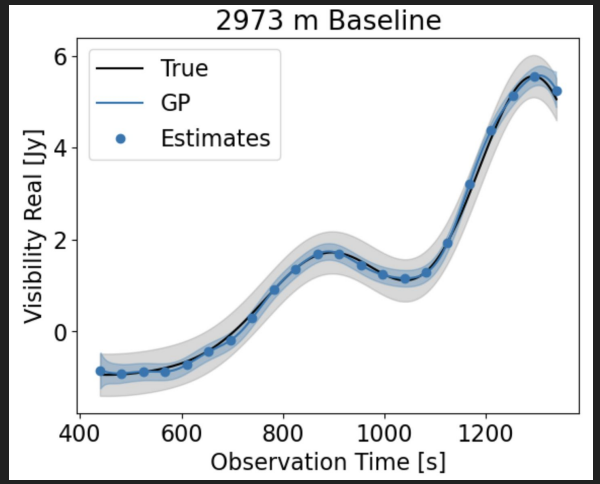

Relative Standard Deviation [%]
Standard Deviation [deg]
Gain Amplitude
Gain Phase
3
1
0.3
0.1
1
3
10
30
Mean Observed Visibility Amplitude [Jy]


RFI
Astronomical
Visibility Amplitude [Jy]
Ant. 28
Ant. 34
Gain Amplitude
Gain Phase [deg]
Time [min]

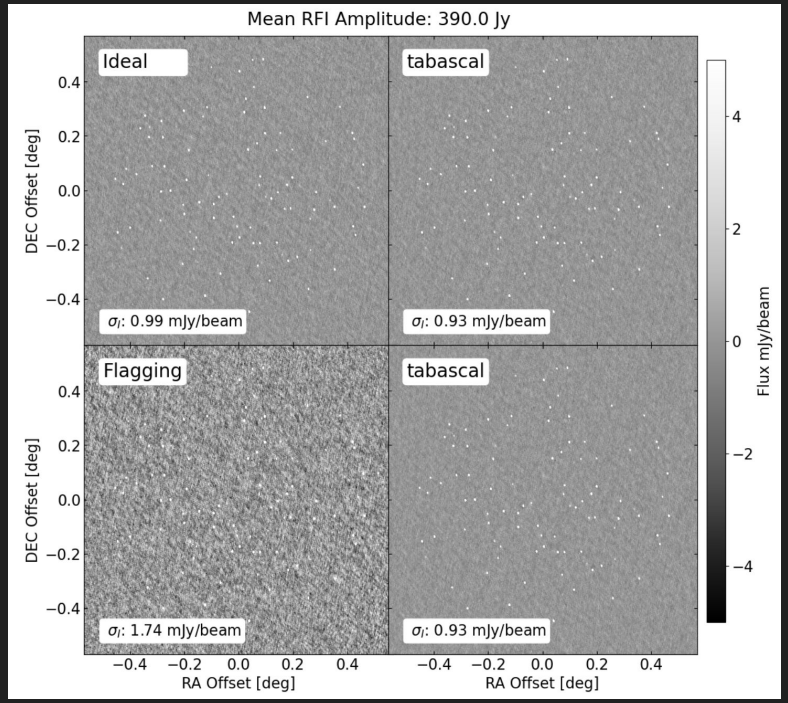
TABASCAL II (2GC)

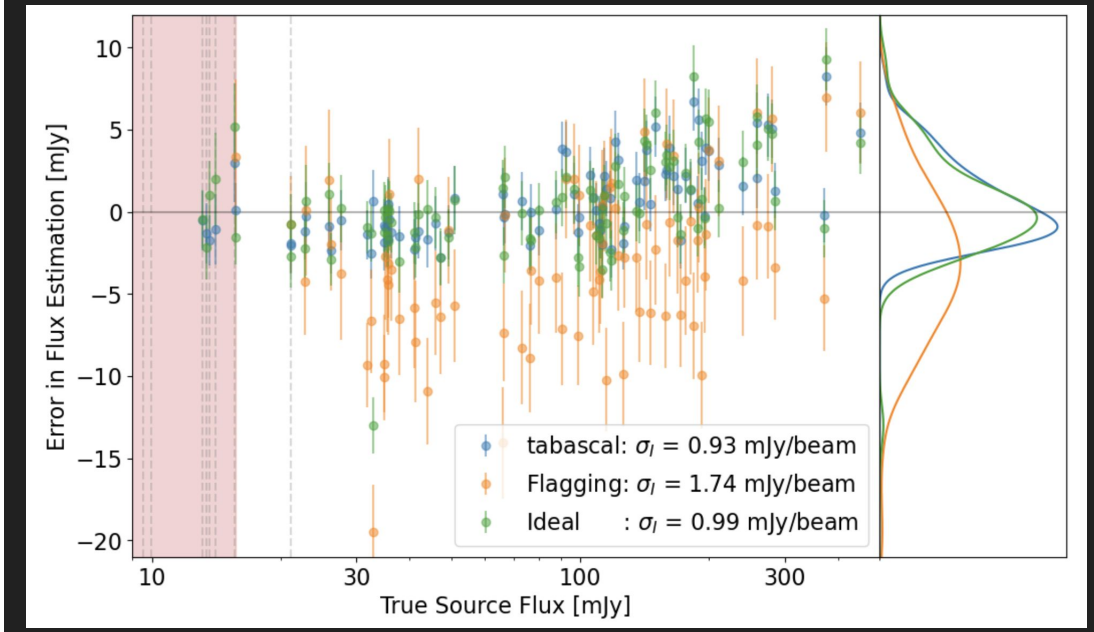
- Use TABASCAL I estimates as a prior for TABASCAL II.
- Use Gaussian processes to reduce the parameter space and enforce smoothness..





TABASCAL II


Mean RFI Amplitude: 390.0 Jy
Ideal
tabascal
Flagging
tabascal
σ_I: 0.99 mJy/beam
σ_I: 0.93 mJy/beam
σ_I: 1.74 mJy/beam
σ_I: 0.93 mJy/beam
DEC Offset [deg]
RA Offset [deg]
Flux mJy/beam


Error in Flux Estimation [mJy]
True Source Flux [mJy]
tabascal: σ_I = 0.93 mJy/beam
Flagging: σ_I = 1.74 mJy/beam
Ideal : σ_I = 0.99 mJy/beam

TABASCAL II - Multiple sources

Satellite constellations

- GNSS - GPS, Galileo, GLONASS, etc.
- Communications - Iridium, Inmarsat, Starlink?
- Earth Observation and Weather

Stationary Sources

- TV and Radio broadcast
- Emission from nearby towns

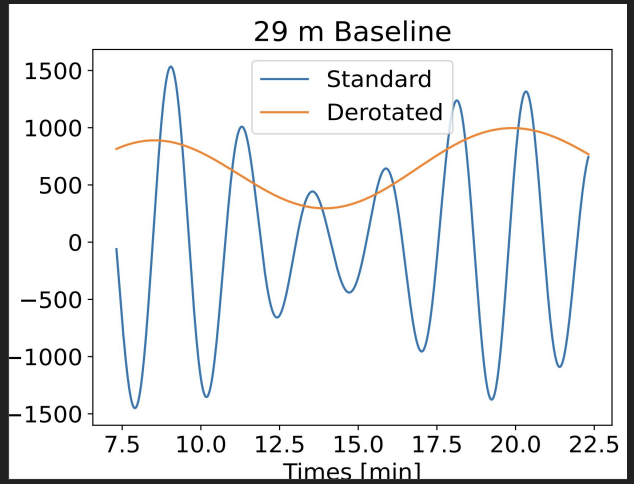
TABASCAL II - Baseline Method

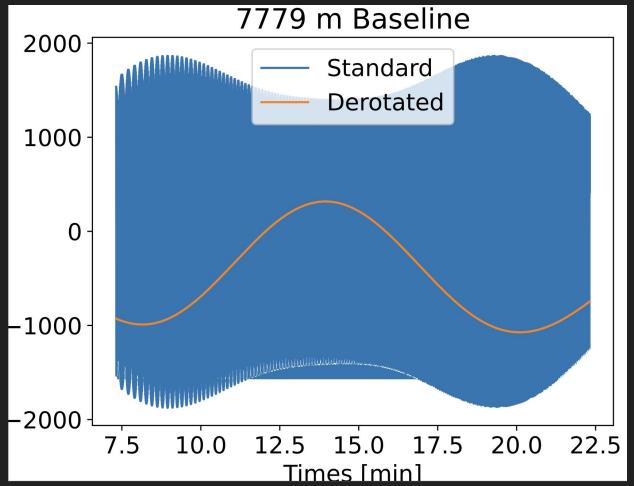
Advantages

- Independent over baselines - better scalability
- Can manage thousands of sources

Disadvantages

- Need to know the trajectory of RFI sources a prior
- Prone to fringe frequency degeneracy





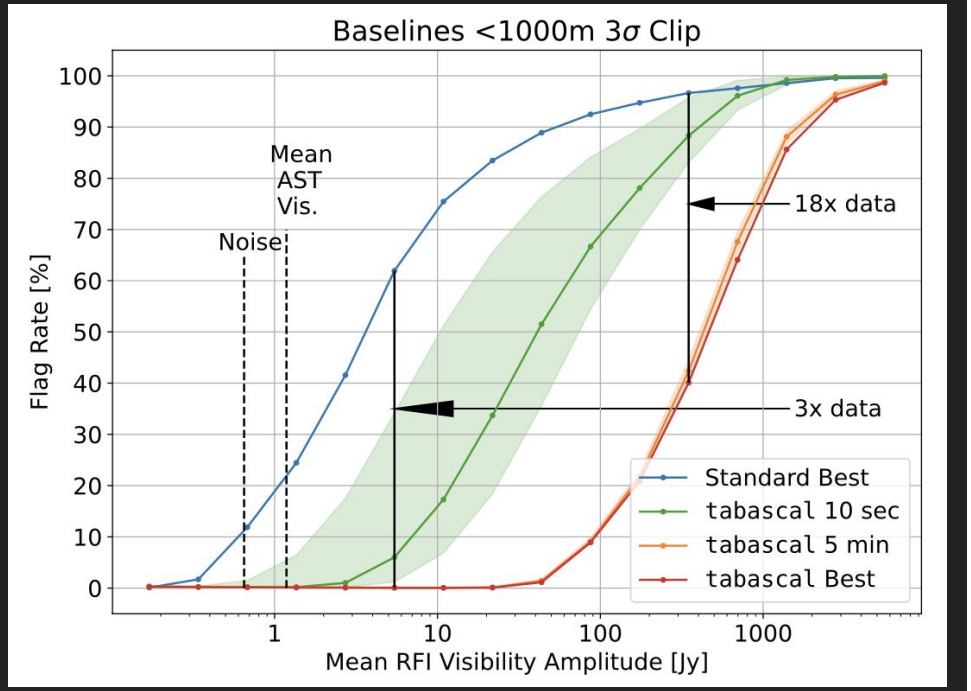
Conclusion

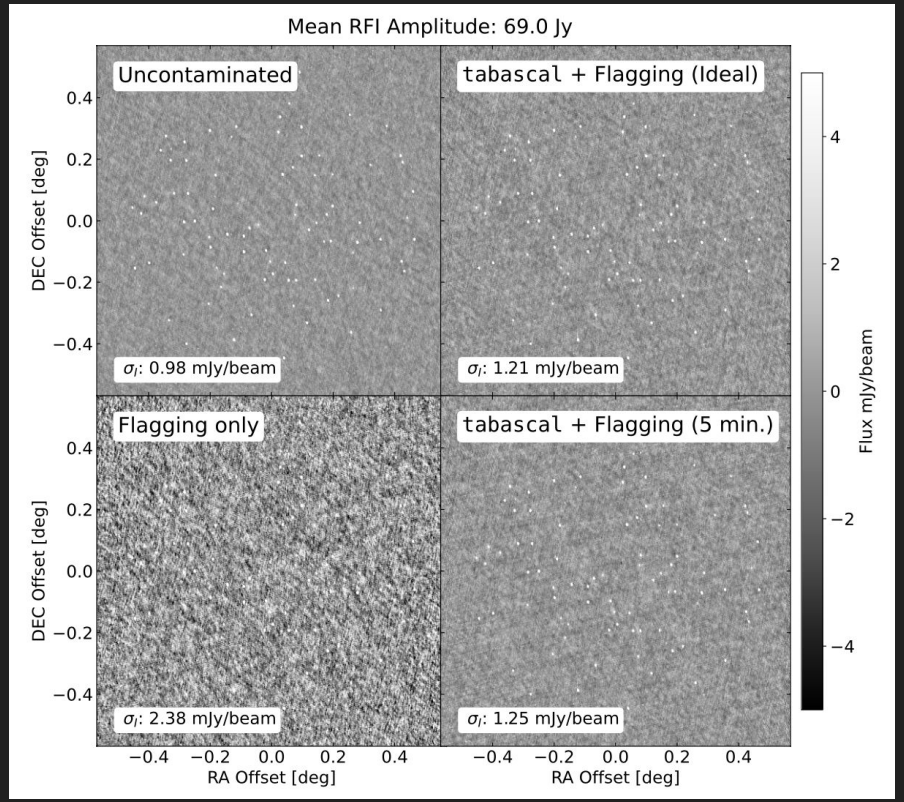
- TABASCAL II can recover astronomical visibilities.
- Recovered visibilities are denoised → improved image fidelity.
- Complex RFI signal is handled
- At the expense of more computation
  - Stronger RFI is possible
  - Multiple RFI sources are possible

Upcoming Work

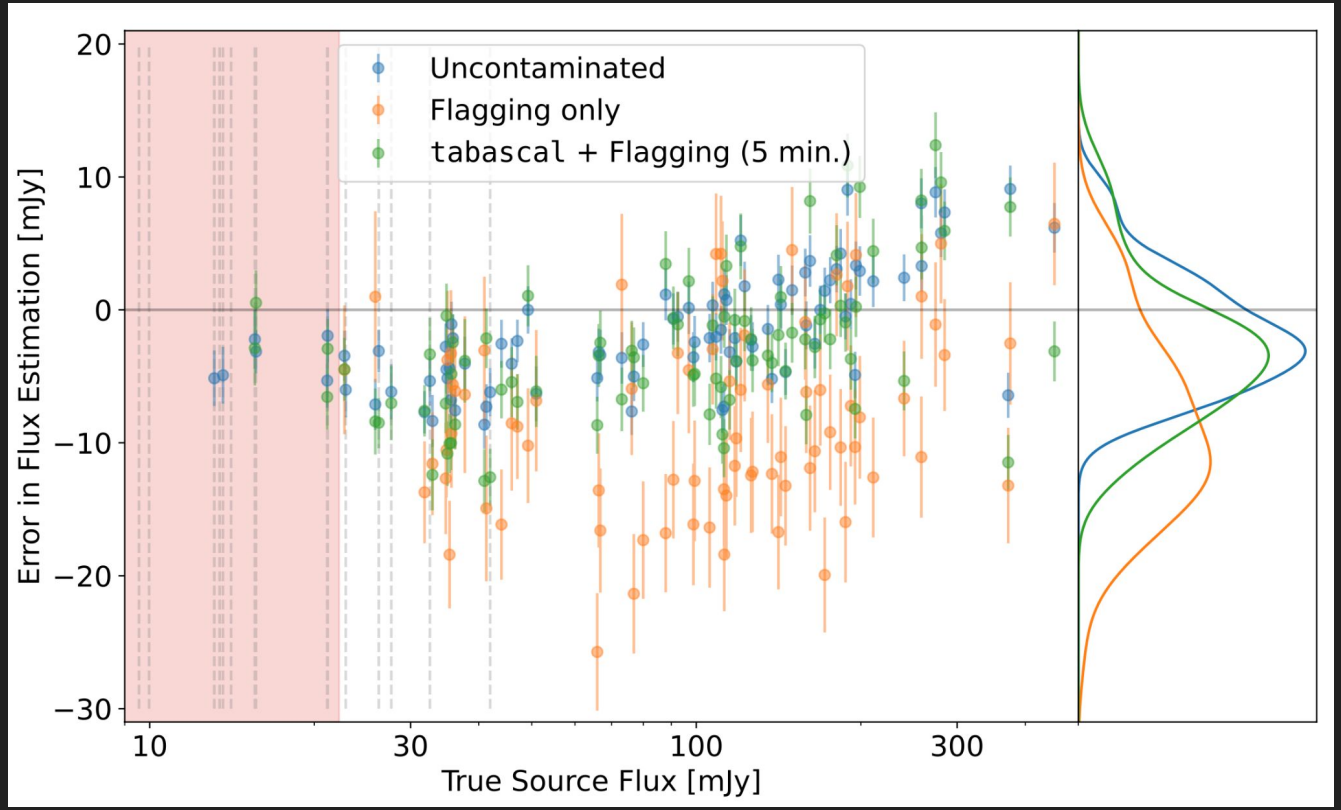
- TABASCAL II paper
- Develop fringe-based baseline method
- Test on real data

TABASCAL I


Baselines <1000m 3σ Clip
Flag Rate [%]
Mean AST Vis.
Noise
18x data
3x data
Standard Best
tabascal 10 sec
tabascal 5 min
tabascal Best
Mean RFI Visibility Amplitude [Jy]


Mean RFI Amplitude: 69.0 Jy
Uncontaminated
tabascal + Flagging (Ideal)
Flagging only
tabascal + Flagging (5 min.)
σI: 0.98 mJy/beam
σI: 1.21 mJy/beam
σI: 2.38 mJy/beam
σI: 1.25 mJy/beam
DEC Offset [deg]
RA Offset [deg]
Flux mJy/beam

TABASCAL I


Uncontaminated
Flagging only
tabascal + Flagging (5 min.)
Error in Flux Estimation [mJy]
True Source Flux [mJy]
20
10
0
−10
−20
−30
10
30
100
300