A New Pipeline for Characterizing and Recording Radio Frequency Interference for the Canadian Hydrogen Intensity Mapping Experiment Fast Radio Burst Project

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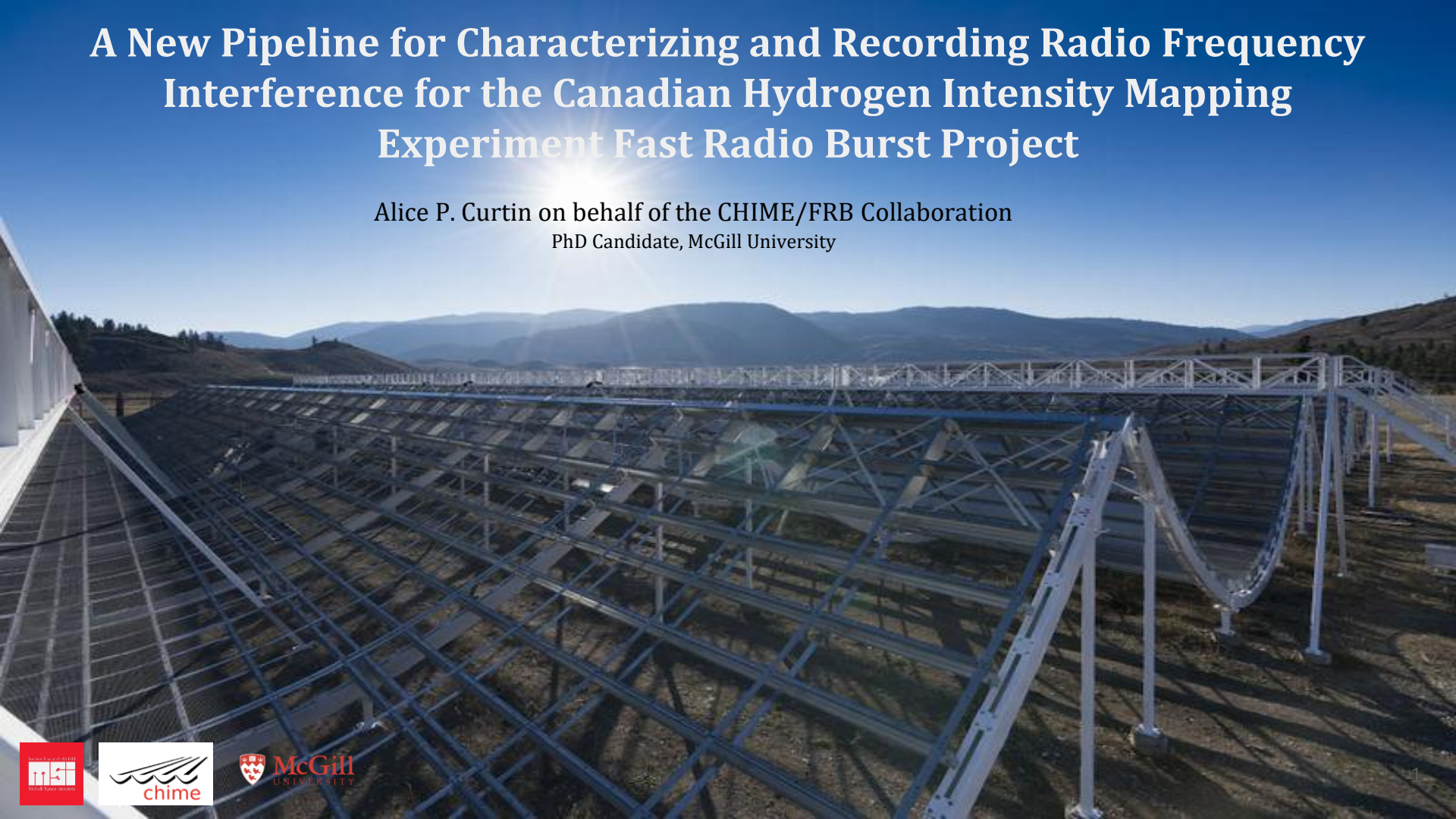


Canadian Hydrogen Intensity Mapping Experiment (CHIME)

- Transit telescope located in radio-quiet zone in Penticton, BC
- Originally built to study the 21-cm hydrogen emission
- Four 100-m x 20-m cylindrical parabolic reflectors
- 400 to 800 MHz with 1024 dual polarization feeds
- Large FOV ~250 deg^2
- Powerful FX correlator

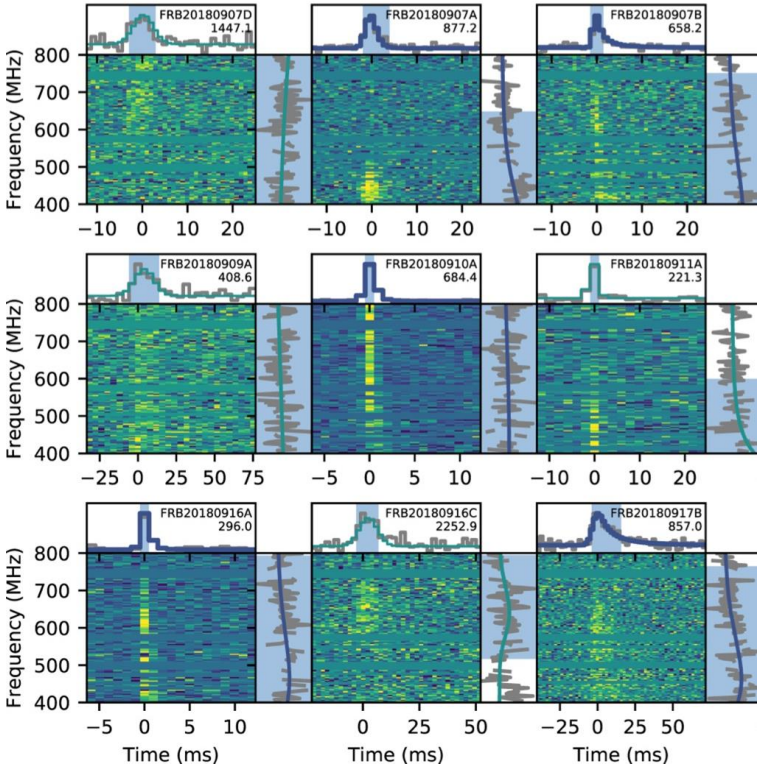
CHIME Fast Radio Burst Project

Transit nature and large FOV = great candidate for blind radio transient searches e.g. fast radio bursts

FRBs:

- Fast (~millisecond), highly energetic (~Jy), extragalactic bursts of energy.
- Very energetic with origins still unknown!
- New probe for studying cosmological parameters and questions along with Galactic and extragalactic environments

Since its commissioning in 2019, CHIME/FRB detected >2000 FRBs



CHIME/FRB Collaboration (2021)

More on CHIME/FRB

Large data rate of ~142 Gb/s = real-time pipeline

L0: FFT beamforming -> 1024 formed beams

L1: RFI removal process; Event detection algorithm

L2/L3: Groups events to determine whether something is astrophysical or RFI; Improves localizations; Determines whether an event is Galactic or Extragalactic; Decides future actions for the event

L4: Implements actions decided in L2/L3

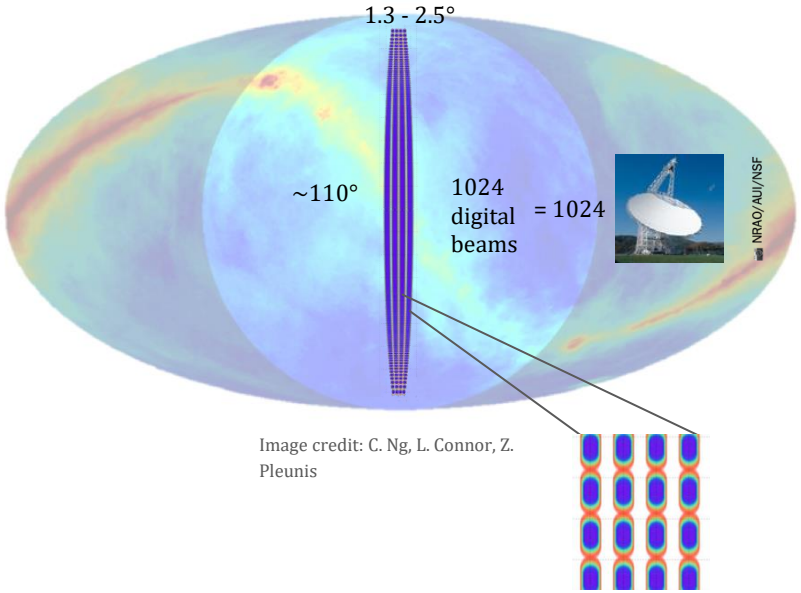
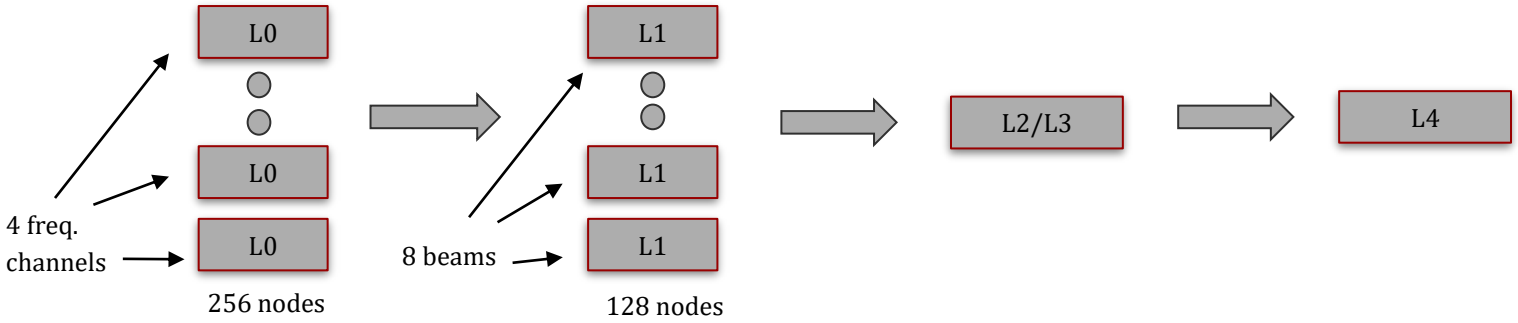


Image credit: C. Ng, L. Connor, Z. Pleunis



Radio Frequency Mitigation at CHIME/FRB

CHIME/FRB's L1 masking process: (see talk by M. Rafiei-Ravandi on Friday at 2:40 pm ET for further details)

- Initial input = gaussian signal (FRB) + non-gaussian outliers (RFI)
- Non-gaussian outliers removed through a chain of transforms
  - Each transform operates on a four second chunk of data (intensity + weights)
  - Clippings: specified intensity amplitude cutoff
  - Detrender: polynomial and spline along both the frequency and time axis to capture broadband RFI signals
  - Sequence of clippings/detrending repeated multiple times

Sources of RFI at CHIME/FRB

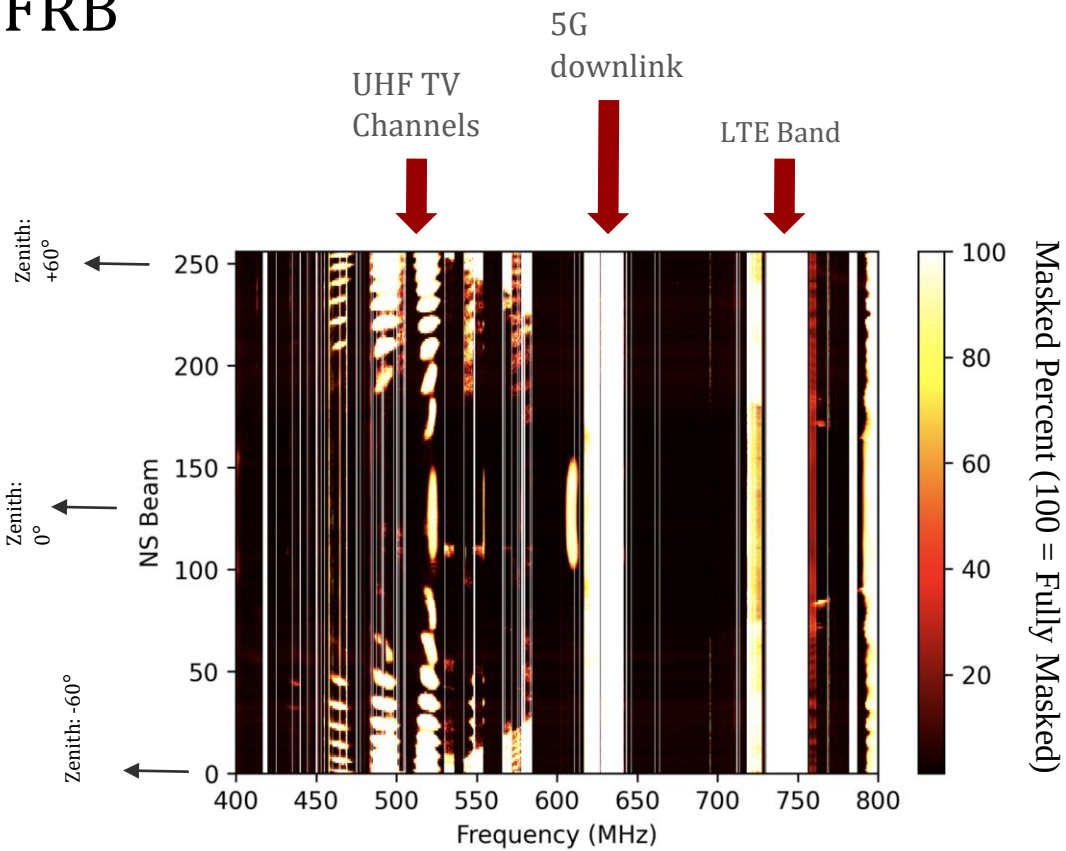
CHIME/FRB operates from 400 to 800 MHz

Sources of RFI:

- Bright astrophysical sources
- LTE band
- UHF TV Channels
- 5G downlink channels

Highly dynamic!

Mask ~22% of our data



Recording RFI Metrics

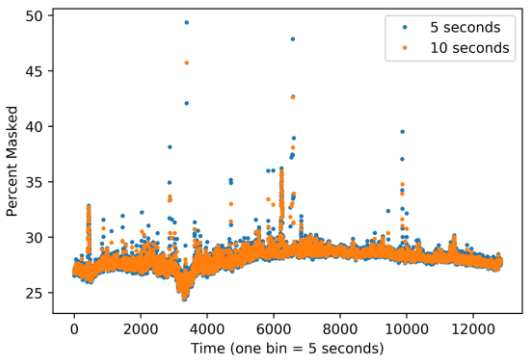
Why do we need to record our RFI?

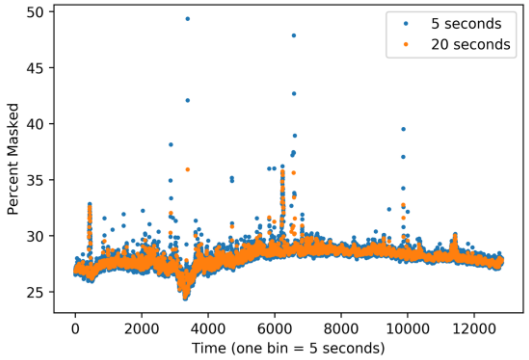
- FRBs ~millisecond timescales, yet there are ~second timescales where the RFI masking is > 50%
- Important for calculating our sky exposure, which affects FRB rate and repetition statistics
- Important for calculating our bandwidth e.g. RFI metrics were used in Josephy et al. (2021) to estimate the bandwidth of CHIME/FRB

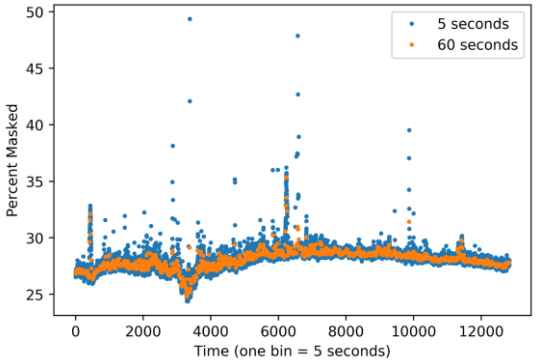
Recording RFI Metrics

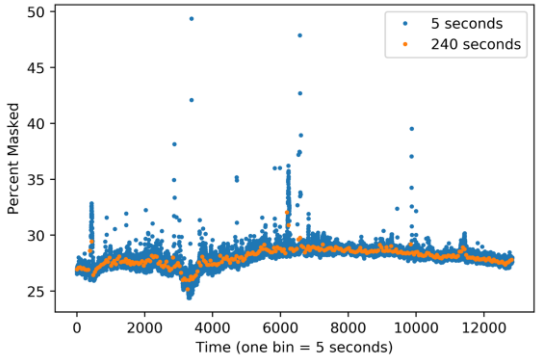
Why is this difficult?

- RFI dynamic on <5 second timescales
- 1024 frequencies, 1024 beams queried at a 4 second cadence = 84T of data per year
- Additionally, need a mechanism to query the data at such a high cadence

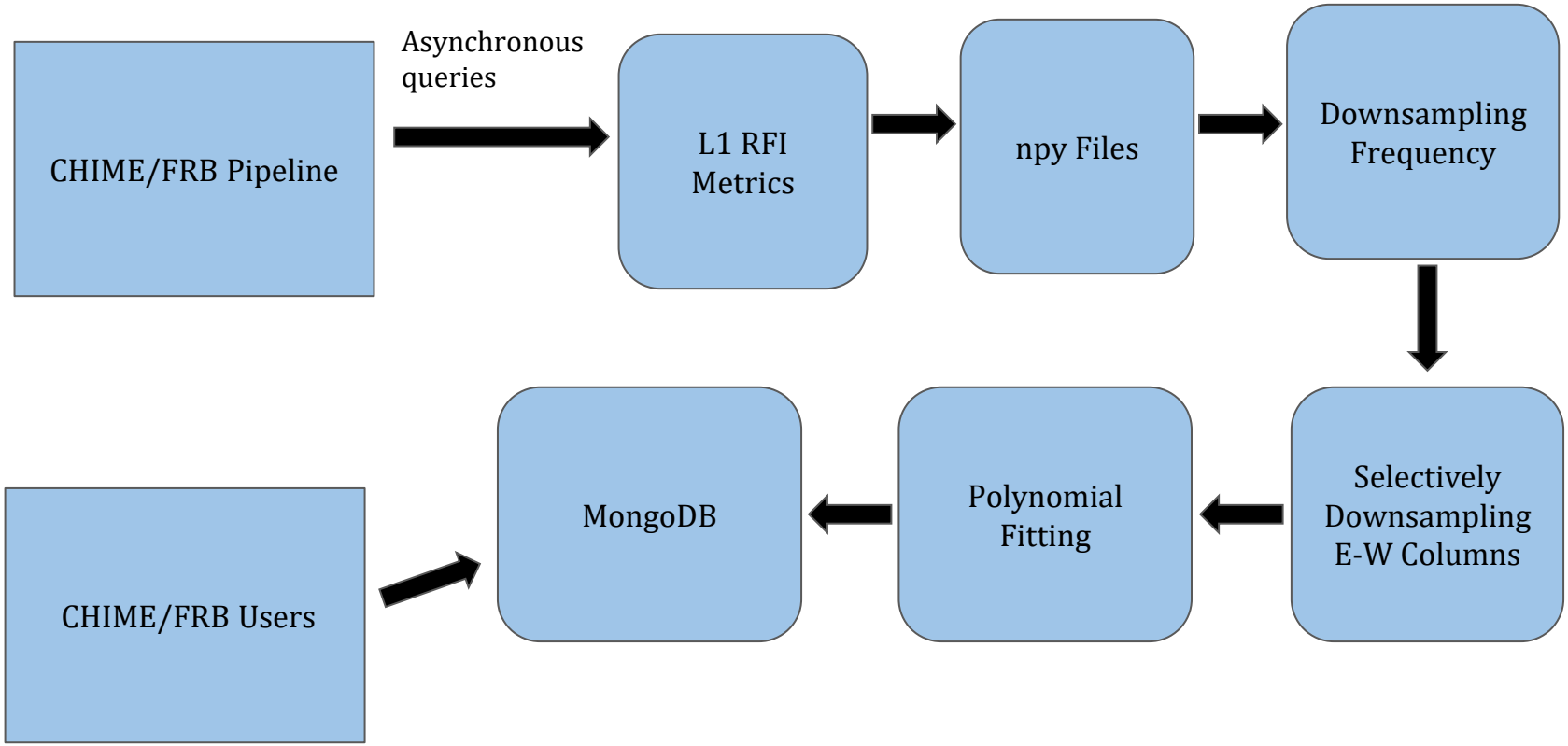






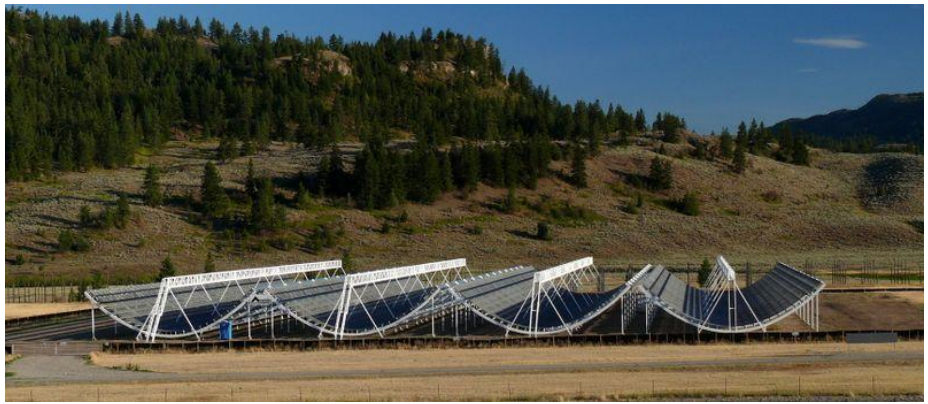


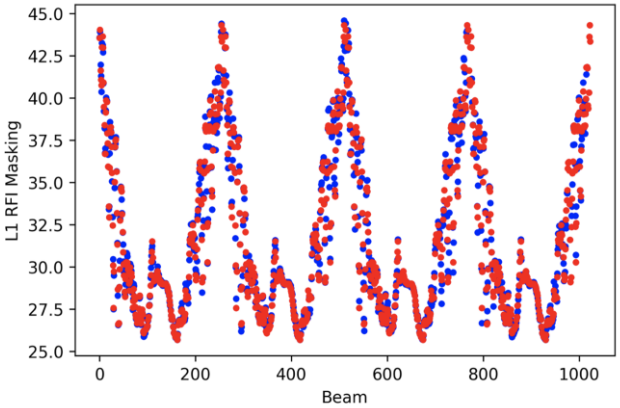
Solution: *rfi-scout*

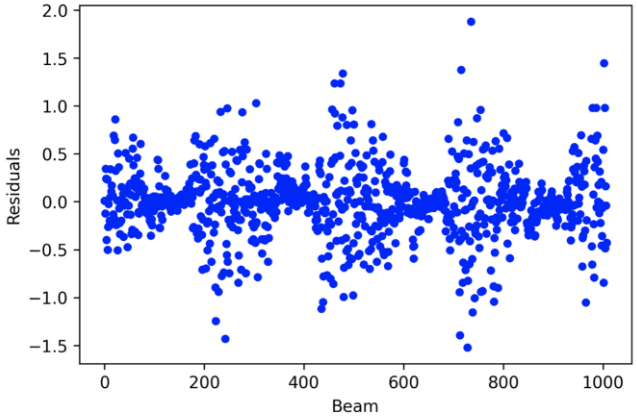


Downsampling: frequency, EW columns

- Downsample in frequency
  - 1024 to 256 frequency channels
  - 75% data reduction
- Downsample over the E-W beam columns
  - 1024 to 256 + outliers beams
  - 57% data reduction

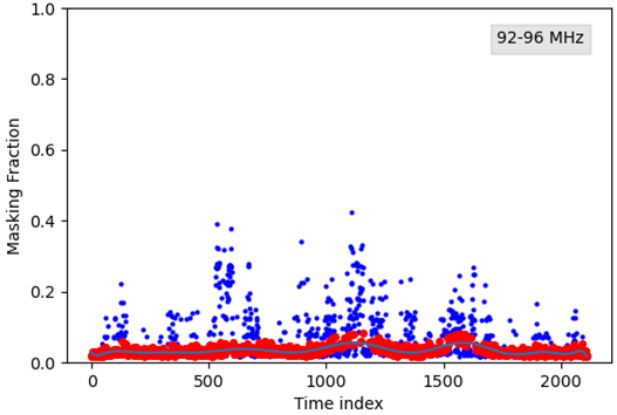


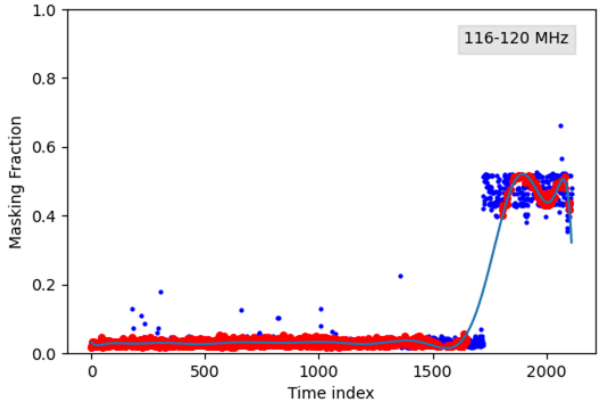


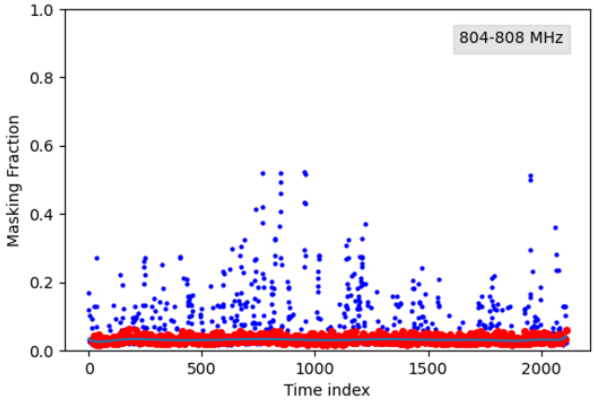


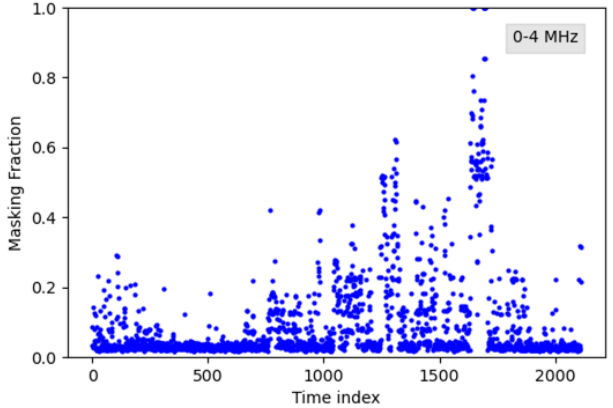
Downsampling: polynomial

- 15 degree polynomial
- Iterative fits (five rounds)
- 4 second sampling cadence
- 3 hours total
- 61% data reduction





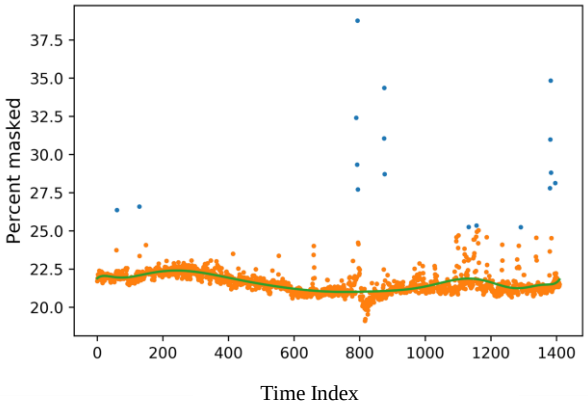


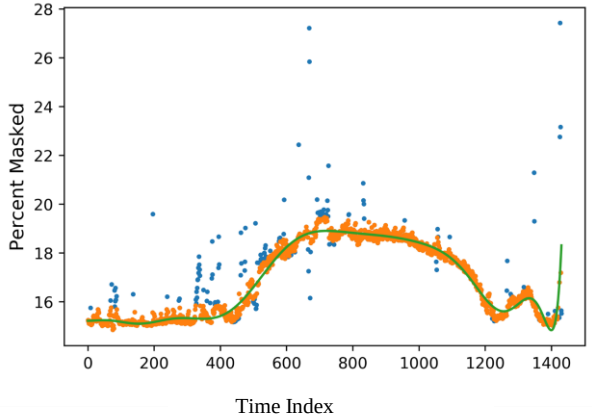


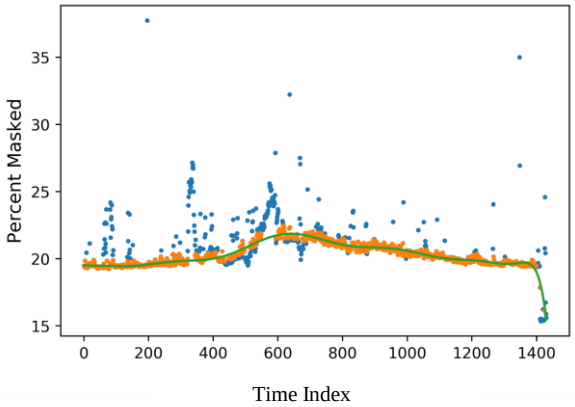
Downsampling: polynomial cont.

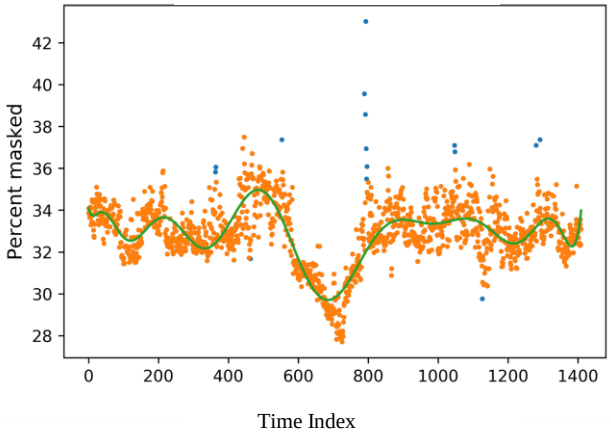
Sampling at a 60 second cadence

24 hours total





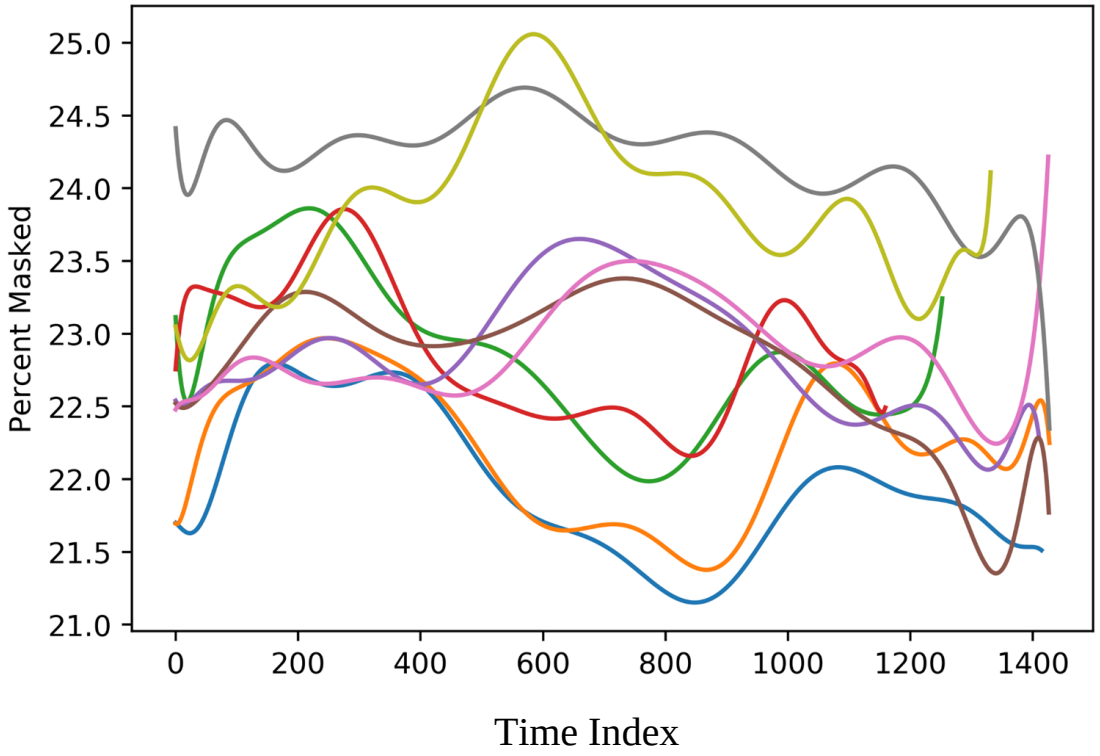




Downling: polynomial fitting over multiple days

Can’t fit the same polynomial over 1+ days

RFI trend greatly varying from day to day



Summarizing

Recording RFI metrics for CHIME/FRB proves difficult:

- Large data rate
- Need to query at high cadences
- Dynamic RFI

New pipeline to overcome this: *rfi-scout*

- Downsampling in frequency: 75% reduction
- Downsampling over E-W beam columns: 57% reduction
- Fitting the data with polynomials: 61 % reduction
- Total reduction: 96%

Currently in implementation phase – stay tuned for scientific impact!

Acknowledgement: This work would not have been possible without the help of Shiny Brar, a software engineer with the CHIME/FRB team.

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