EXPERIMENTING WITH GENERATIVE ADVERSARIAL NETWORKS FOR POST-CORRELATION IDENTIFICATION OF RFI

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WHAT?

RFI = Radio Frequency Interference

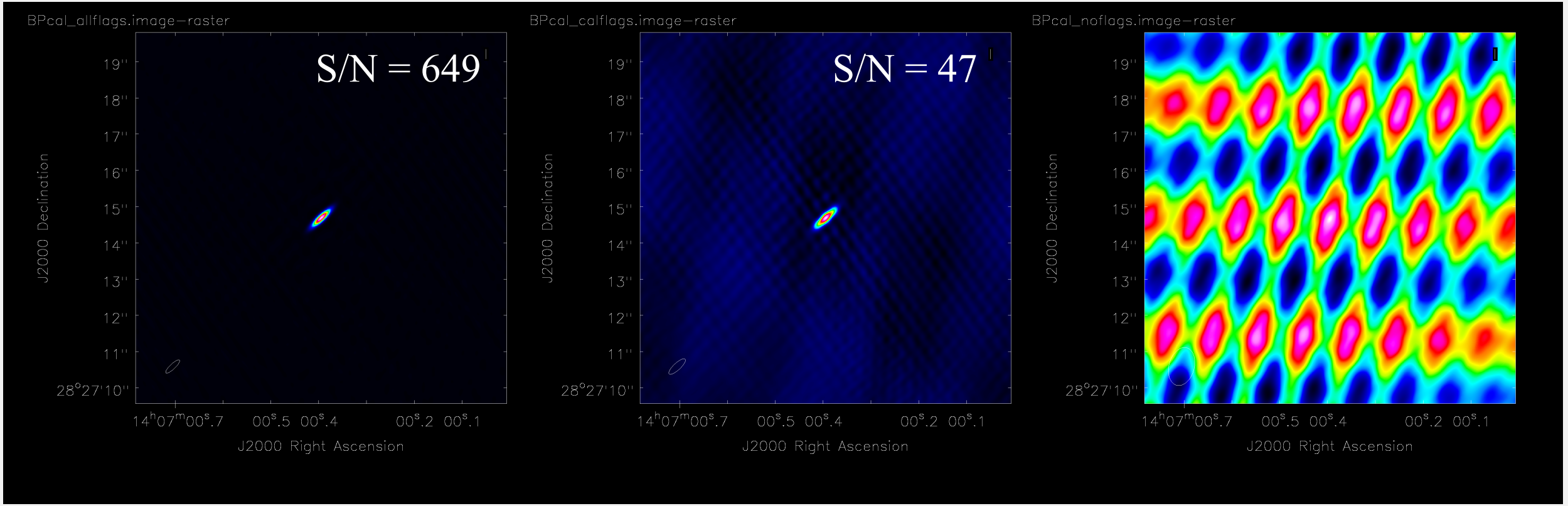
Any signal that is not astronomical in nature:

- Phones
- Planes
- Television
- Satellites
- Lightning
- Microwave Ovens
  - Petroff E., et al., 2015, MNRAS, 451, 3933

And it's getting worse…

WHY?

Removing RFI is **critical** for good calibration + imaging



HOW?

There is no universal method because of varying ‘RFI environments’

Many observatories implement their own hardware and software that are optimised for their environment

An incomplete list of methods/tools:

- Clipping
- TFCrop
- Rflag
- AOFlagger*
- The old fashioned way…

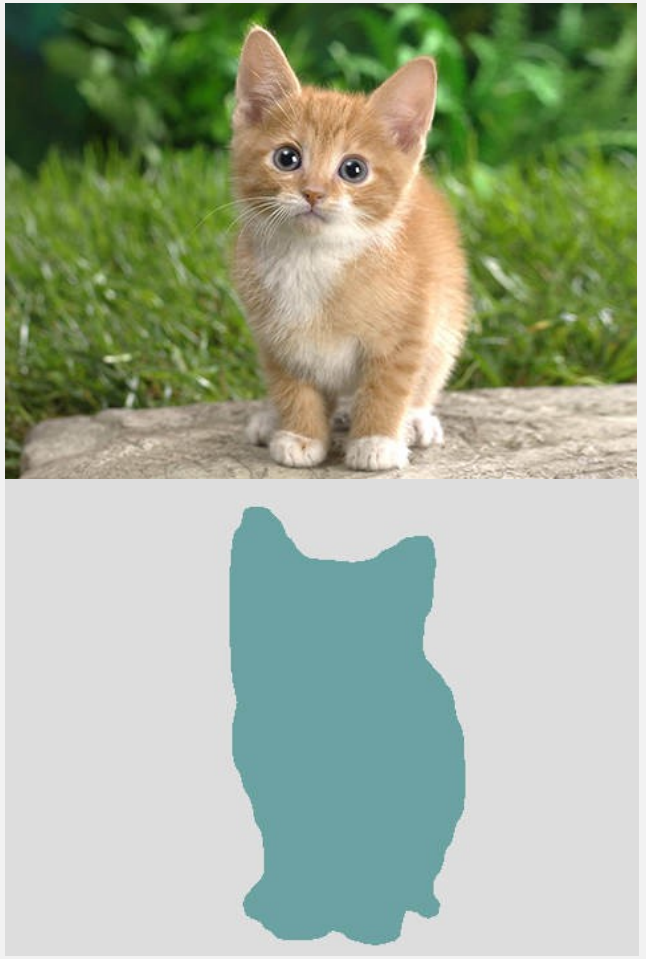
Tools tend to operate on a time-frequency image (spectrogram) and create an **RFI mask** to cover regions that should not be used in calibration

*Offringa et al. 2012, A&A, 539, A95

MACHINE LEARNING IN ASTRONOMY

Another incomplete list of ML applications:

- Object classification
- Catalogue construction
- Transient detection



Producing an RFI mask is called **Image Segmentation**

I have chosen to use Generative Adversarial Networks (GANs), following Li et al. 2021

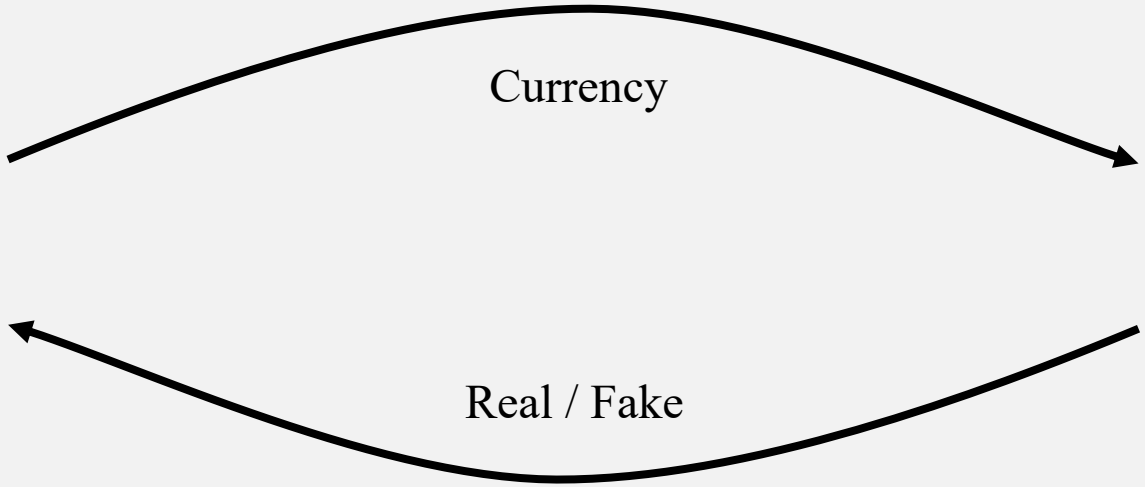
GENERATIVE ADVERSARIAL NETWORKS

Using the analogy proposed by Goodfellow et al. 2014:

Consider a team of Counterfeiters vs the Police

Counterfeiters
Objective: Produce fake currency that passes as real

They are a '**Generator**'



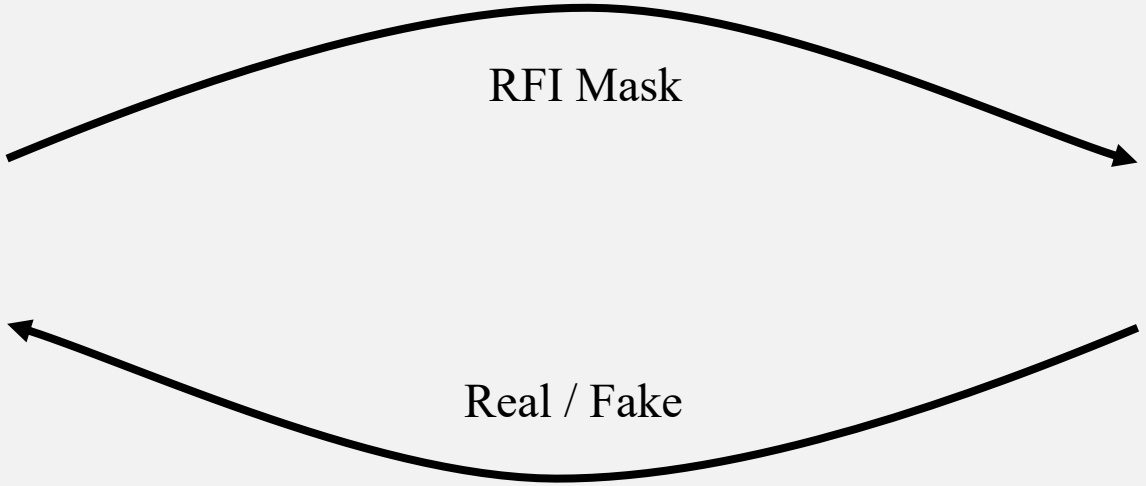
Police Objective:
Separate real currency from fake currency

They are a '**Discriminator**'

Over time, as each side pursues their respective goal, **the fake currency will become indistinguishable from real currency**

Mapping this analogy onto the problem of identifying RFI:

Generator's Objective:
Produce an RFI mask that tricks the discriminator into classifying it as 'real'



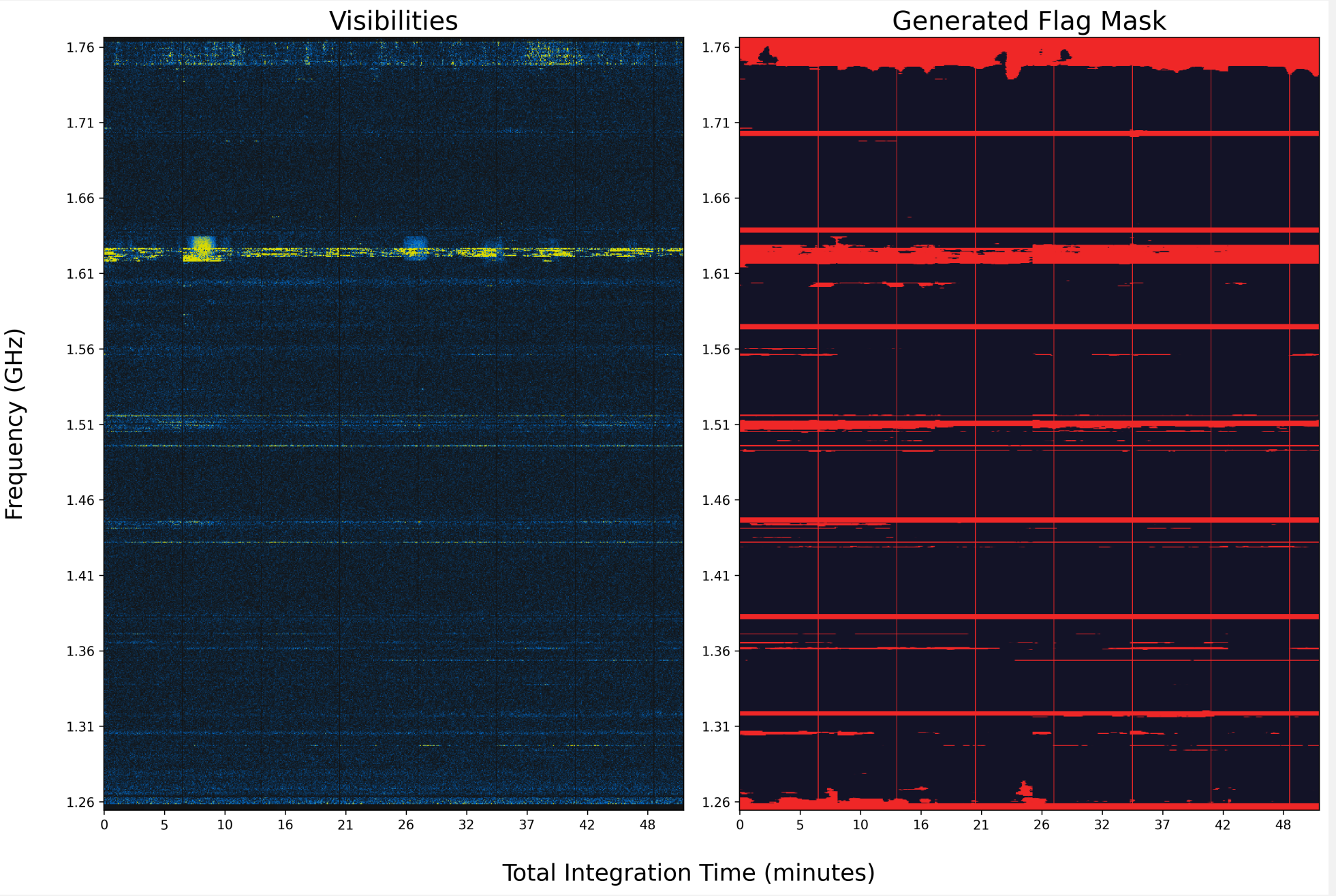
Discriminators Objective:
Separate 'fake' generated RFI masks from 'real' RFI masks

Over many iterations, **the generator will produce RFI masks that pass as 'real'**

We get to choose what 'real' looks like!

RESULTS

- Trained using ~6hrs e-MERLIN phase calibrator observation
- Manually flagged 15 baselines and 2 polarisations
- Results are looking good!



CONCLUSIONS SO FAR

There is significant **potential**:

- The accuracy of the training set appears to be well preserved
- Even trained on a small amount of data, results are acceptable
- With an initial time investment, no further input is required

But…

- Time is money. Observatories need solid evidence before investing in models
- Not optimised yet
- ML models are **only as good as the data they were trained on**. Our model is only useable for certain 1.4GHz e-MERLIN observations.

WHAT NEXT?

We plan to test it against current methods, and score based on image quality

This will all be documented in a publication (at some point)

The true scope of the technique is much larger:

- Modifications to pre- and post-processing
- Modifying the loss functions to include extra information
- Models can be trained for many different situations:
  - Field
  - Baseline/Antenna
  - Frequency
  - Day/Night
  - Seasonal
  - Direction-dependent

FURTHER READING

Generative Adversarial Networks:

- Goodfellow et al., 2014, Advances in NeurIPS
- Li et al., 2021, Astronomy & Computing, 36

Image Segmentation:

- Minaee et al., 2021, IEEE Transactions on Pattern Analysis and Machine Intelligence, 44, 7

Radio Frequency Interference:

- Offringa et al., 2010, MNRAS, 405, 155
- An et al., 2017, Acta Astronomica Sinica, 58, 43
- Fridman & Baan, 2001, A&A, 378, 327

Any comments, queries, suggestions, or thoughts…

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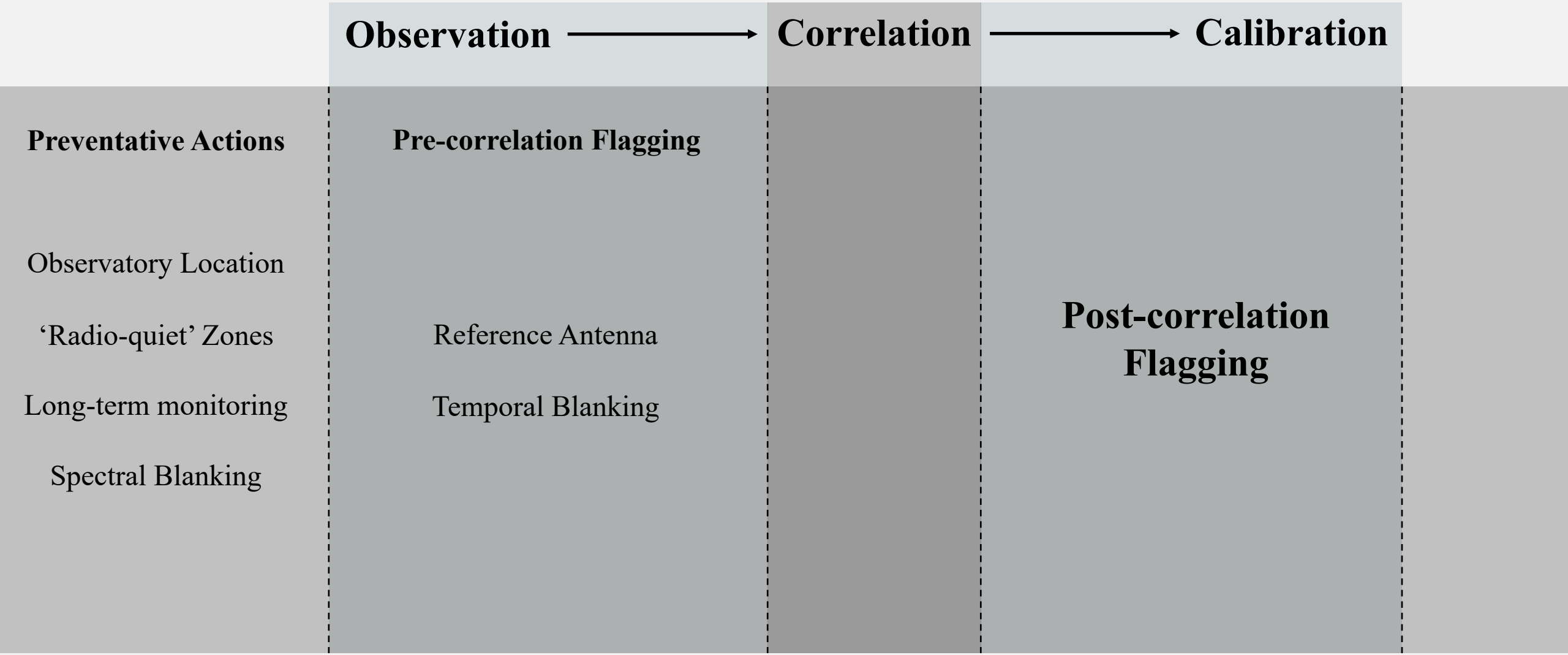
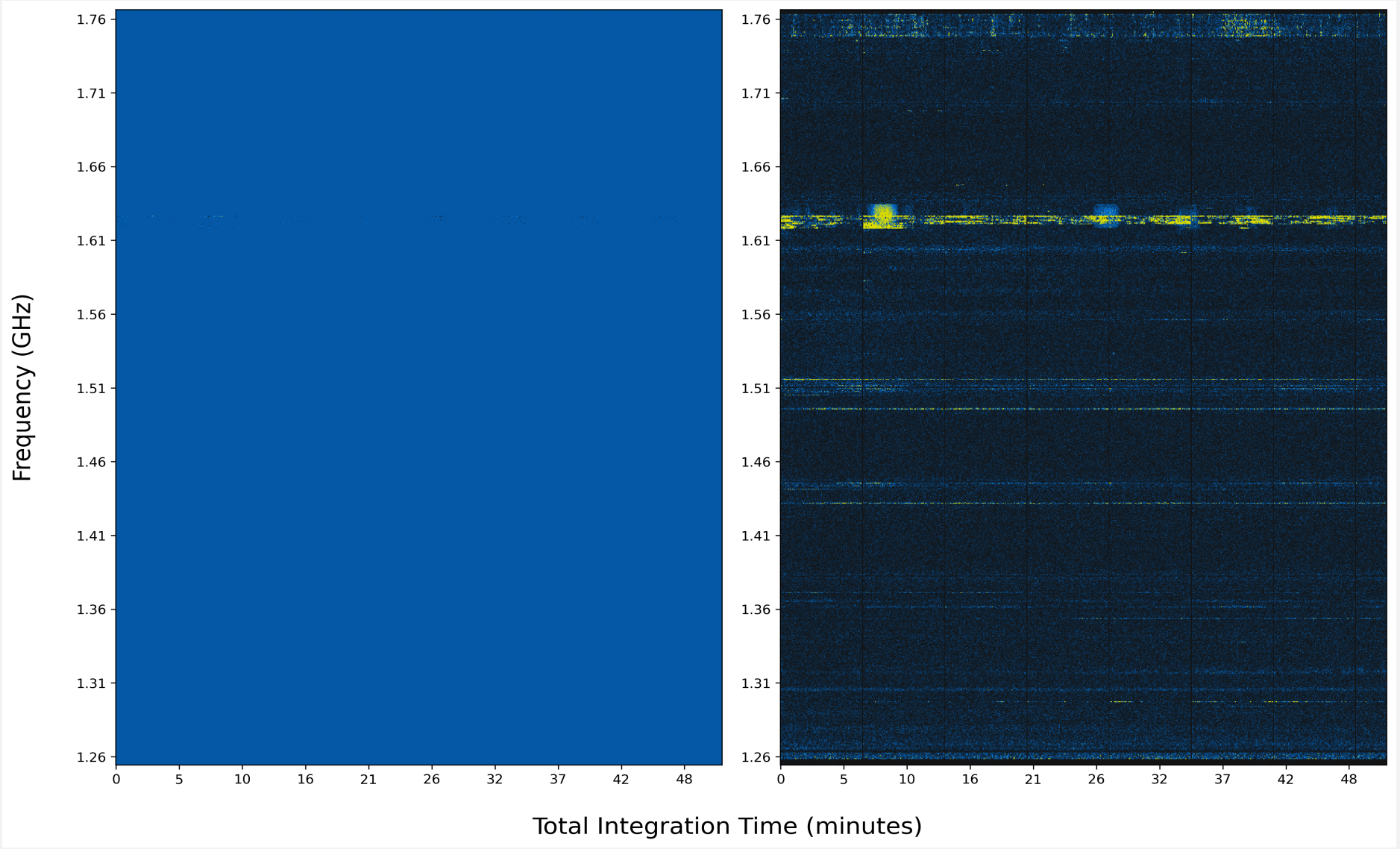
WHEN?


Observation
Correlation
Calibration
Preventative Actions
Observatory Location
‘Radio-quiet’ Zones
Long-term monitoring
Spectral Blanking
Pre-correlation Flagging
Reference Antenna
Temporal Blanking
Post-correlation Flagging

APPLYING THE GAN TECHNIQUE

Some pre-processing required for the generator to ‘see’ the RFI



APPLYING THE GAN TECHNIQUE

We apply only modest pre-processing:

- Surface Removal
- Absolute values
- Winsorizing

There is also scope for **post**-processing on the RFI mask, though we don't do that