Extracting Meaningful Features from Early-Science Radio Data

Matthew Alger (ANU/Data61)
Naomi McClure-Griffiths (ANU)
Cheng Soon Ong (Data61/ANU)

Slides: http://www.mso.anu.edu.au/~alger/c3dis-2019

POSSUM
POLARISATION SKY SURVEY OF THE UNIVERSE'S MAGNETISM

Australian National University

DATA 61

CSIRO

Australian Square Kilometre Array Pathfinder

- Huge 30 deg^2 field of view
- Fast!
- 32 antennae
- >2 PB of science data so far

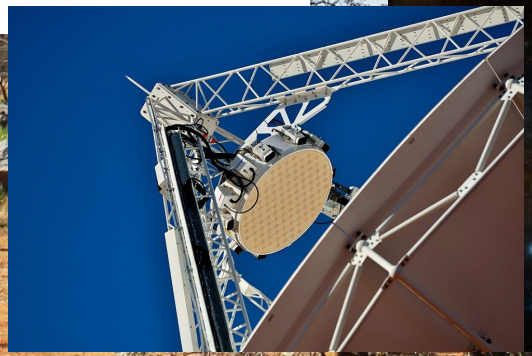
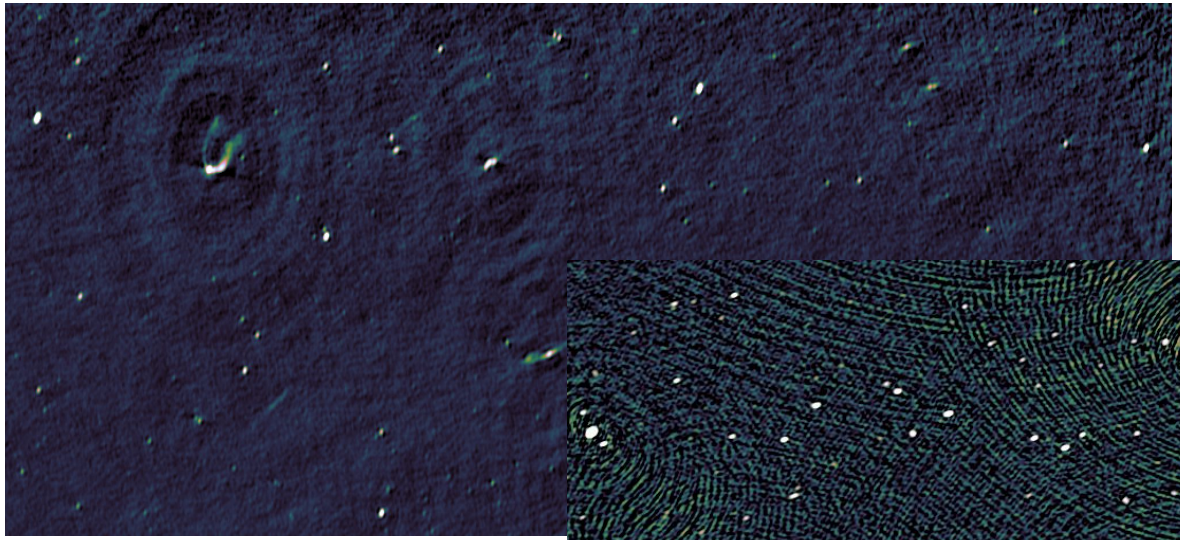


Image: CSIRO

Early-science data



ELAIS-S1 observed with ATCA (courtesy of Tom Franzen).

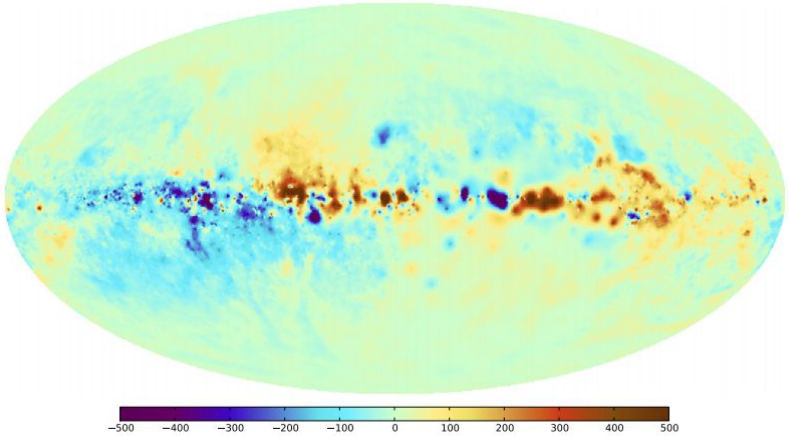
Early POSSUM data observed with ASKAP.

Goals

1. Denoise
2. Get useful features for downstream

POSSUM

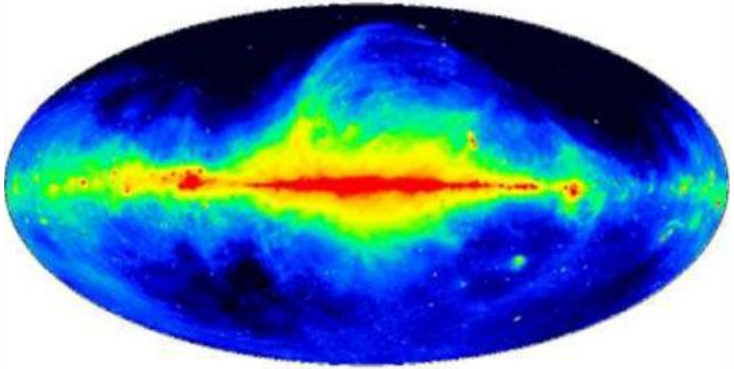
- Polarised “all-sky” survey to complement EMU
- ~1,000,000 polarised radio sources
- Broad benefits to astronomical magnetic field research

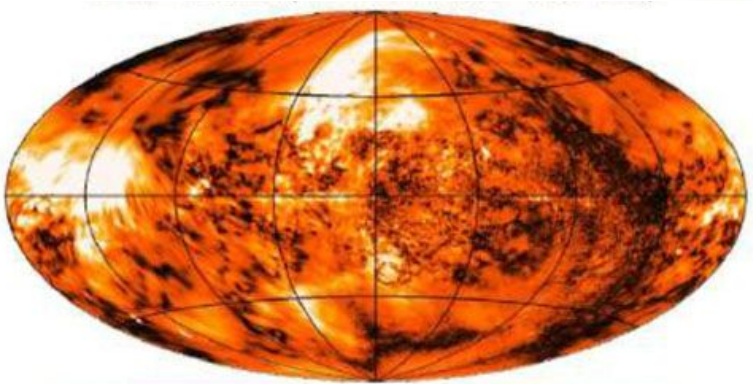


Oppermann+12 Faraday map of the galaxy.

Polarisation

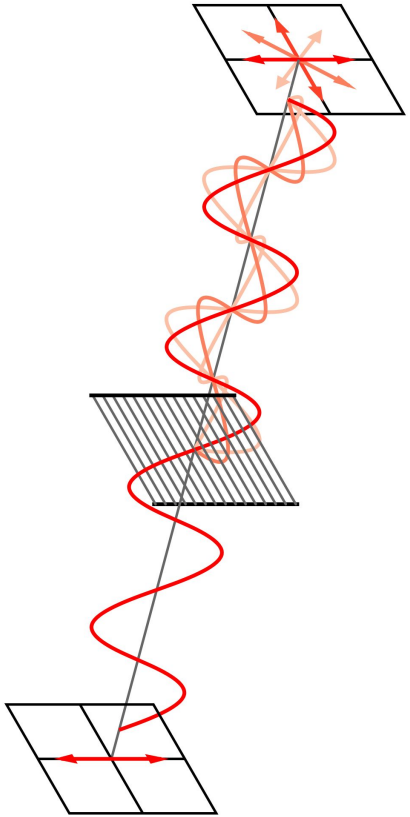
Total radio intensity.





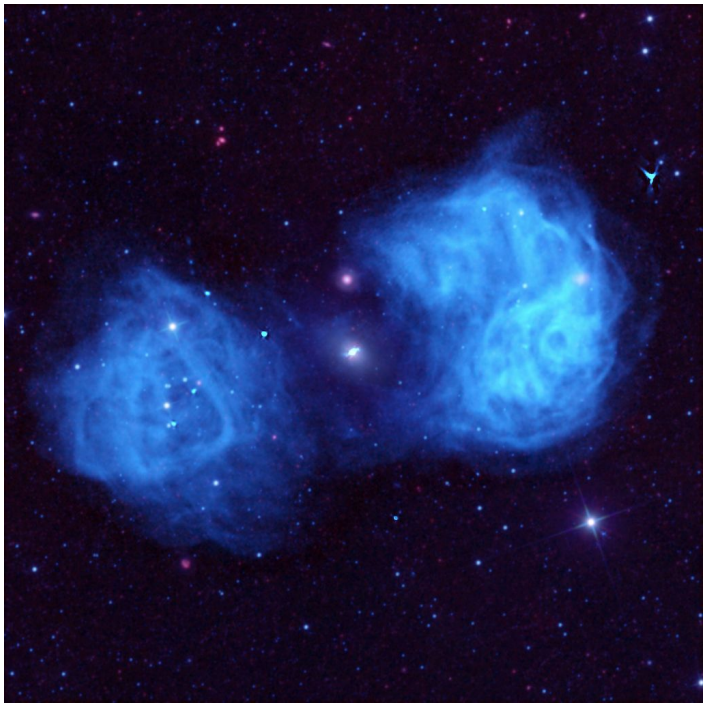
Polarised intensity.

(Reich 1982; Wolleben et al. 2006; Testori et al. 2008).

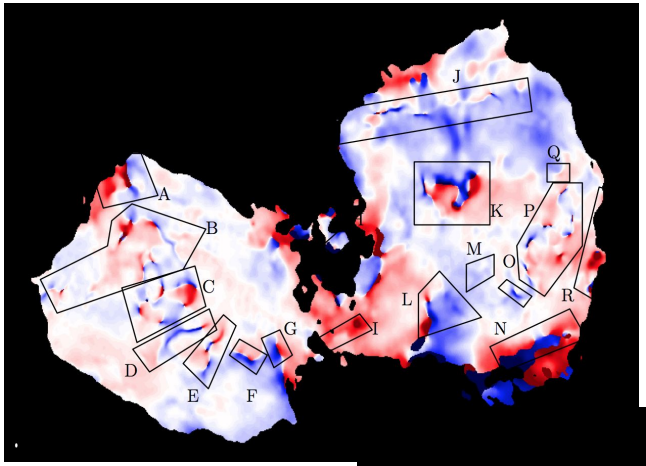


Polarised waves. (http://physicsopenlab.org)

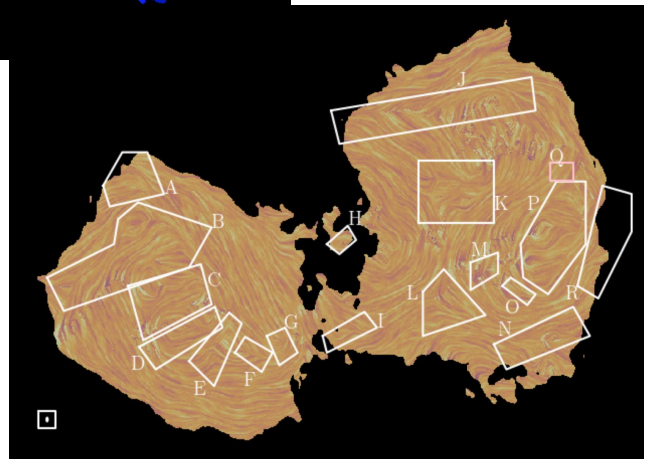
Polarisation



Fornax A in radio continuum (DRAO).

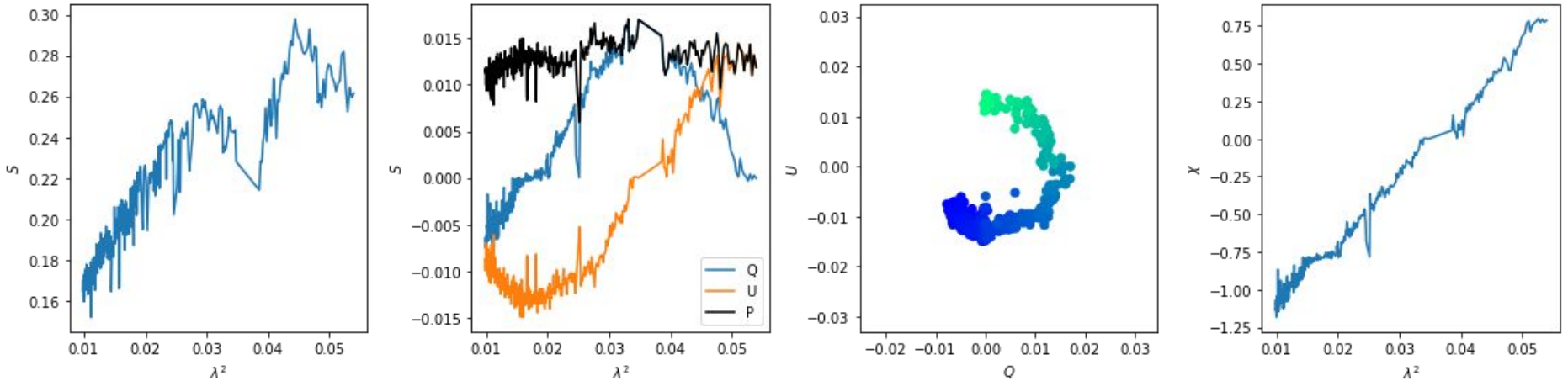


Peak Faraday depth (Anderson+18).



Magnetic field orientation (Anderson+18).

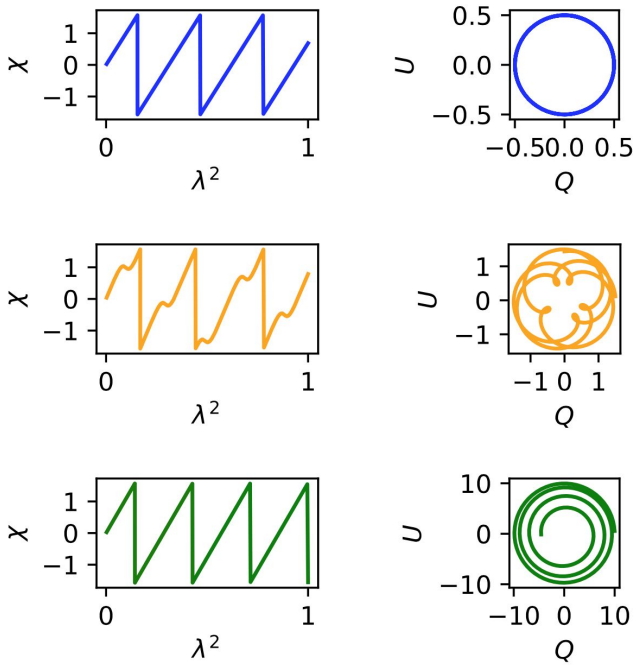
Polarised radio sources



A simple polarised radio source observed with ATCA (courtesy of Jack Livingston).
Left to right: Total intensity, polarised intensity, linear polarisation plane, polarisation angle.

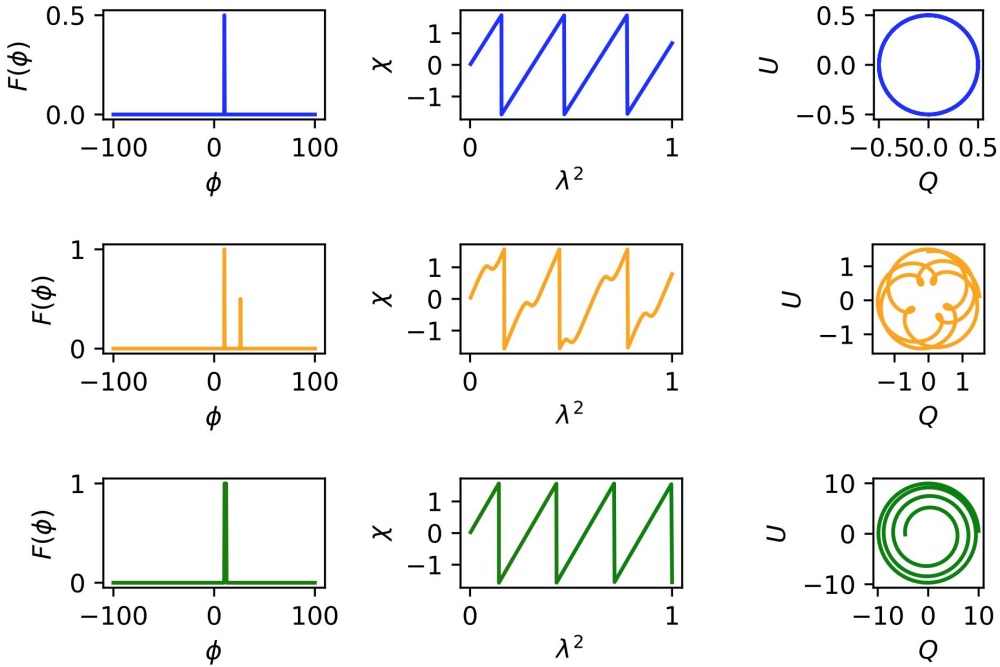
Polarised radio sources

- Simple sources (“screens”) with angle linear in squared wavelength
- Overlapping sources with superimposed rotations
- “Thick” sources with rotation and emission (“slabs”)
  - Depolarisation…



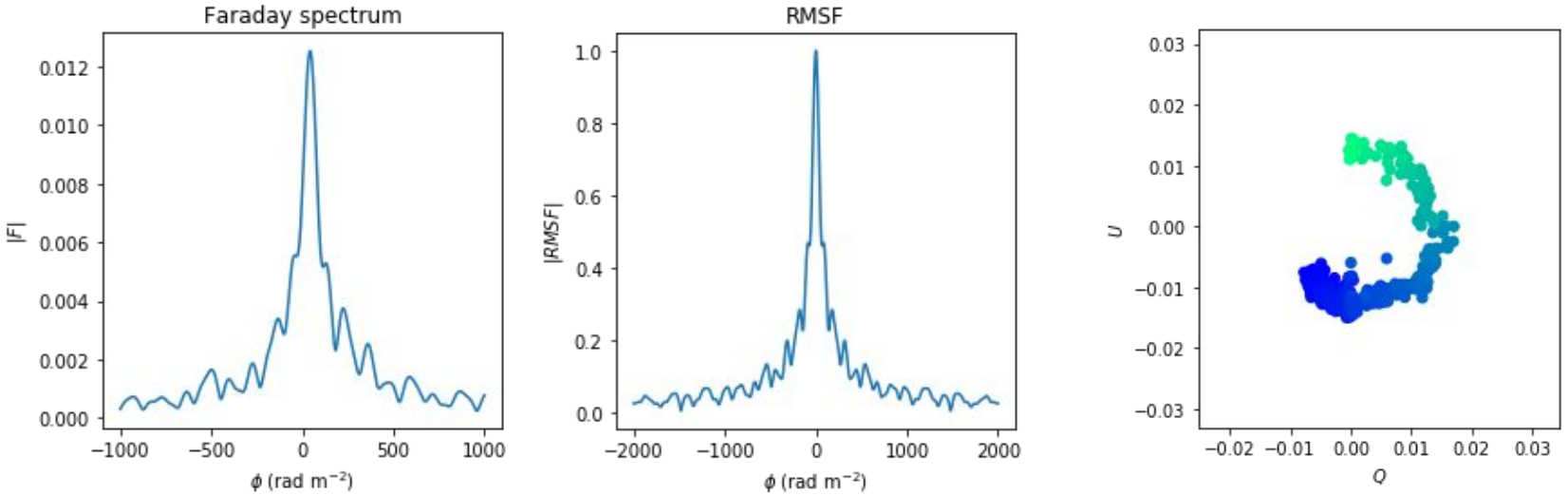
Faraday spectra

- Fourier transform* of polarised spectrum
- Conjugate axis is the *Faraday depth*
- Obvious separation of complexities



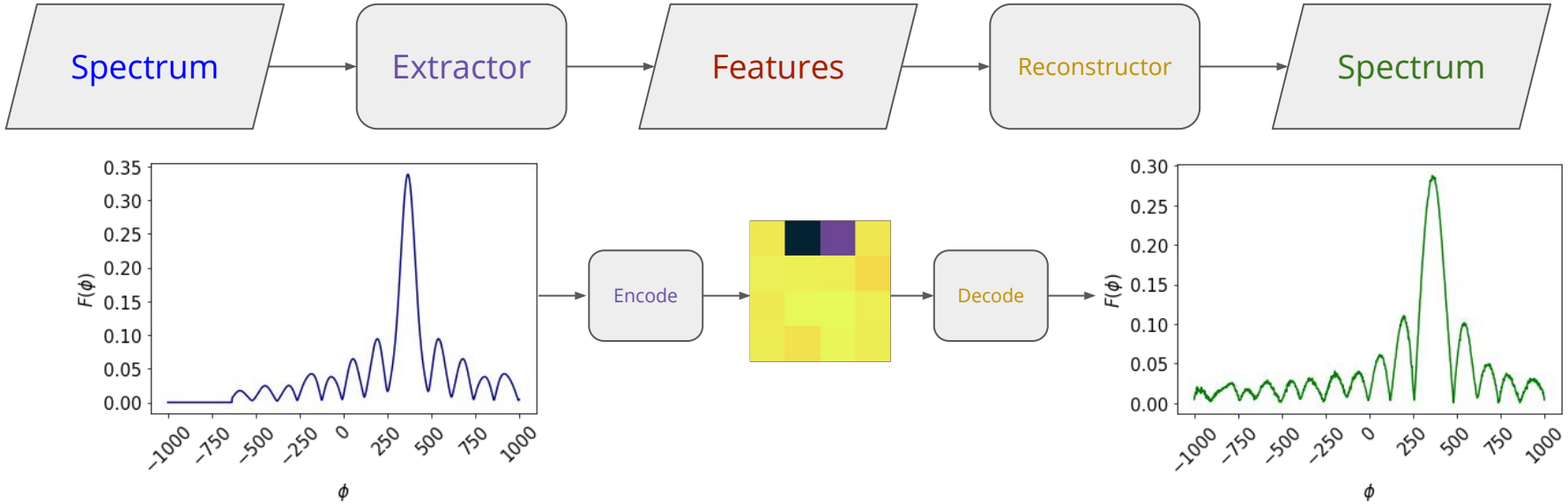
Polarised radio sources

Observed spectra noisy and convolved with a spread function (RMSF):



Faraday spectrum of the previous source along with its spread function (courtesy of Jack Livingston).

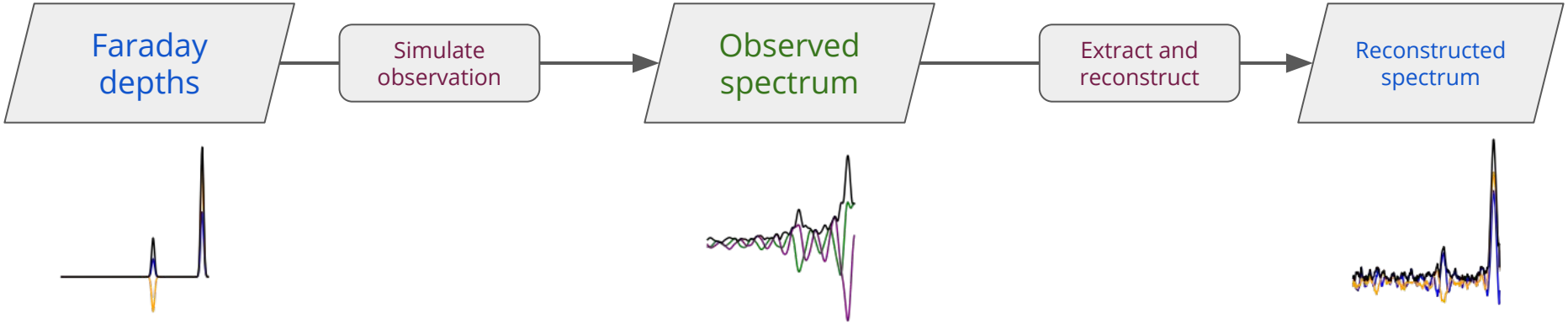
Autoencoders



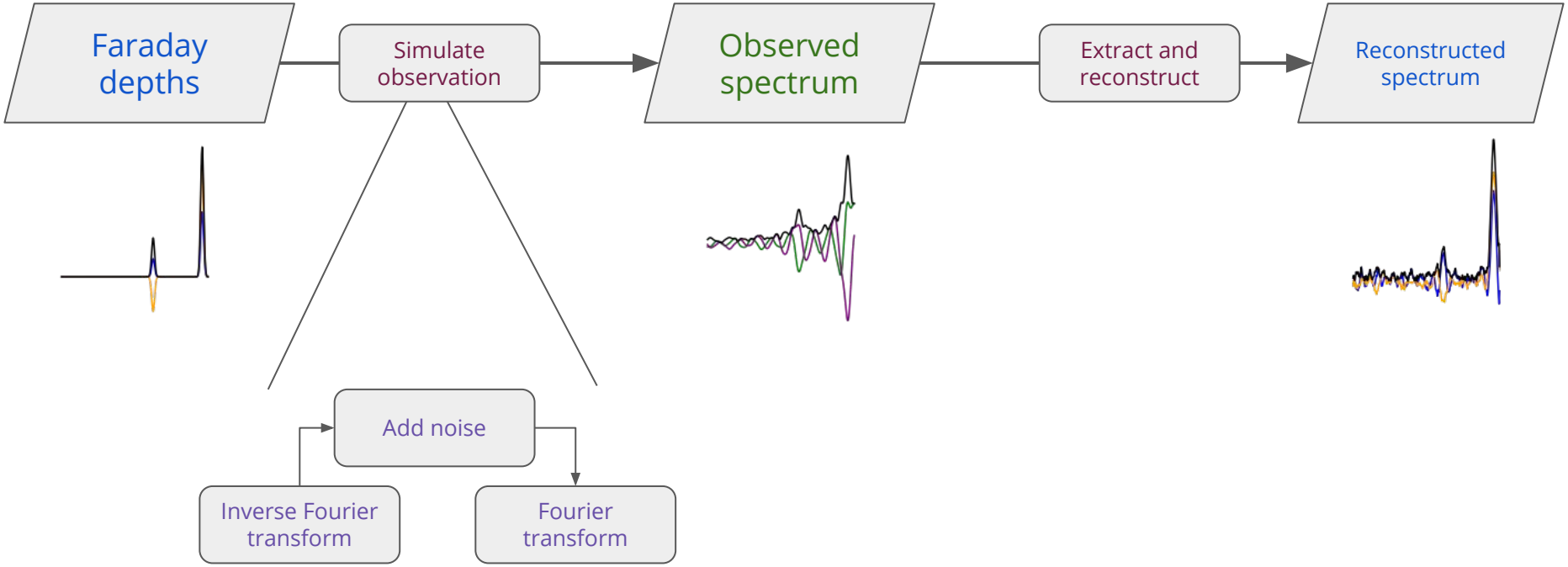
Goals

1. Denoise
    - Add noise, then map back to the no-noise version
    - Learn to “ignore” noise
2. Get useful features for downstream
    - Unclear where these features will best come from
    - Choose a model architecture that explicitly outputs features

Faraday spectrum feature extractor



Faraday spectrum feature extractor



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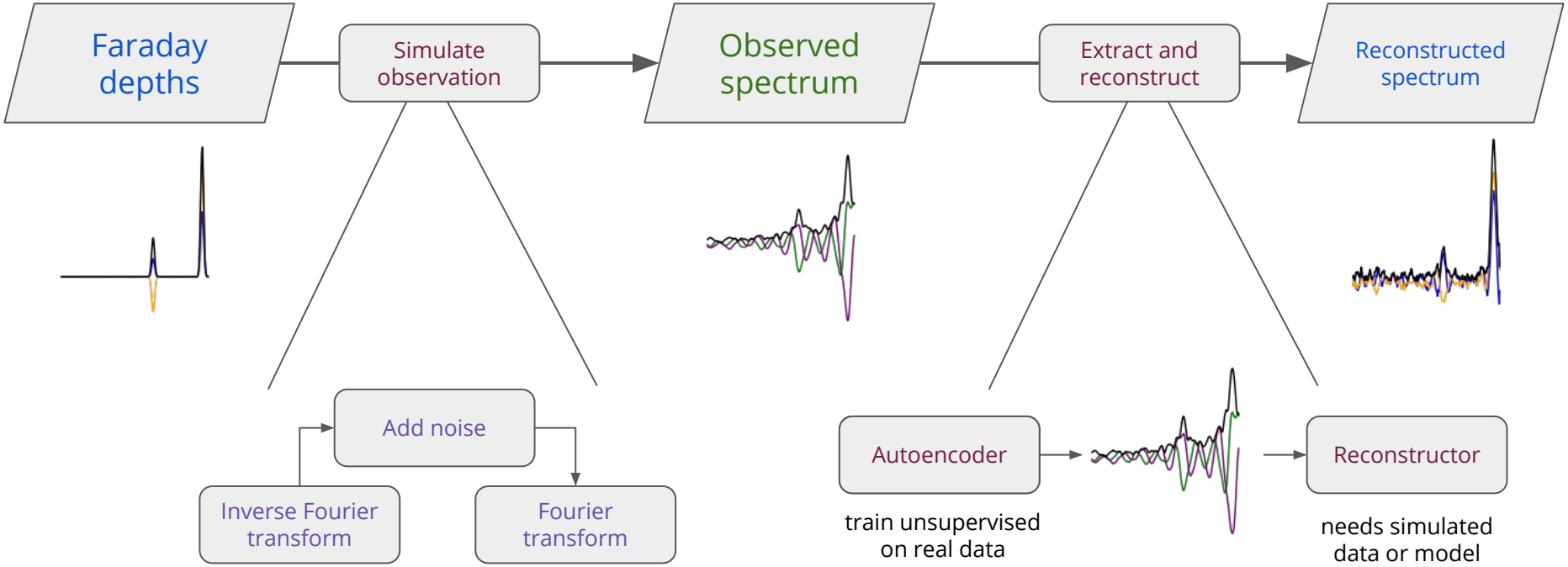
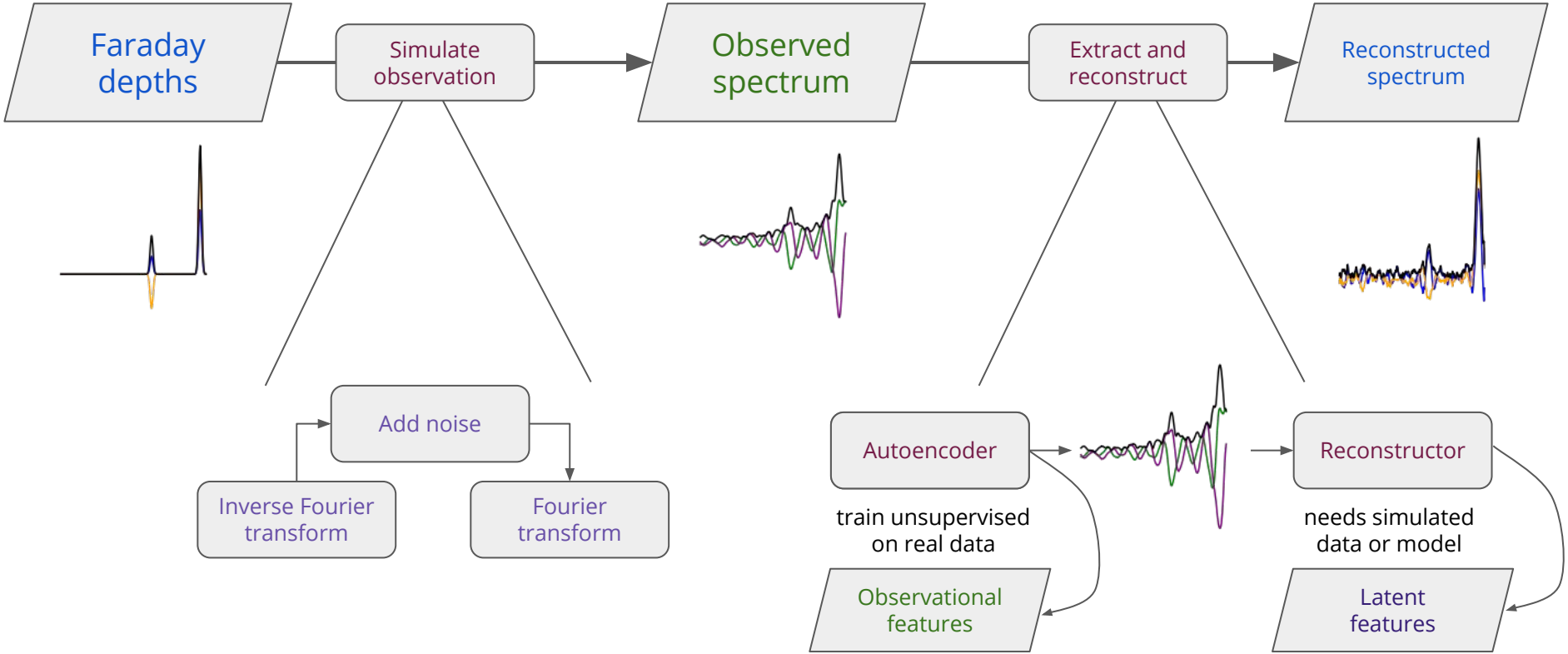
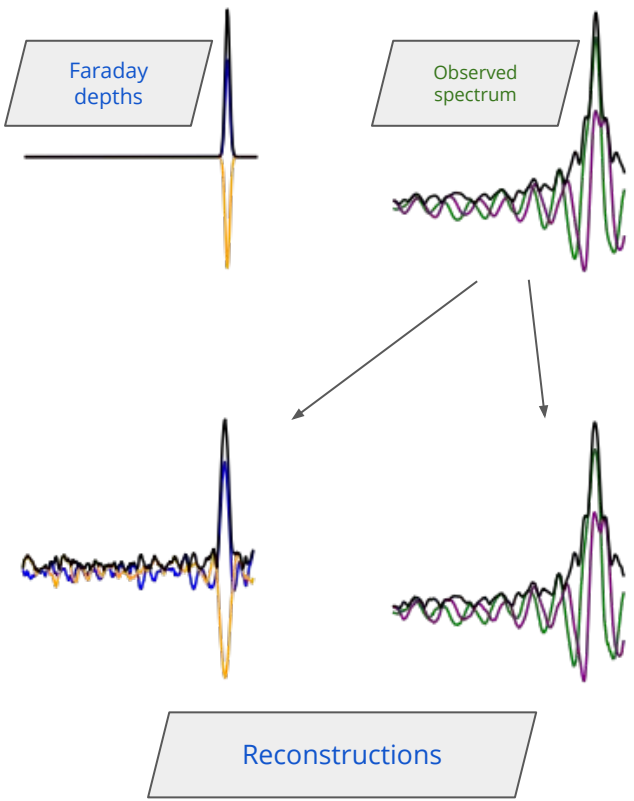
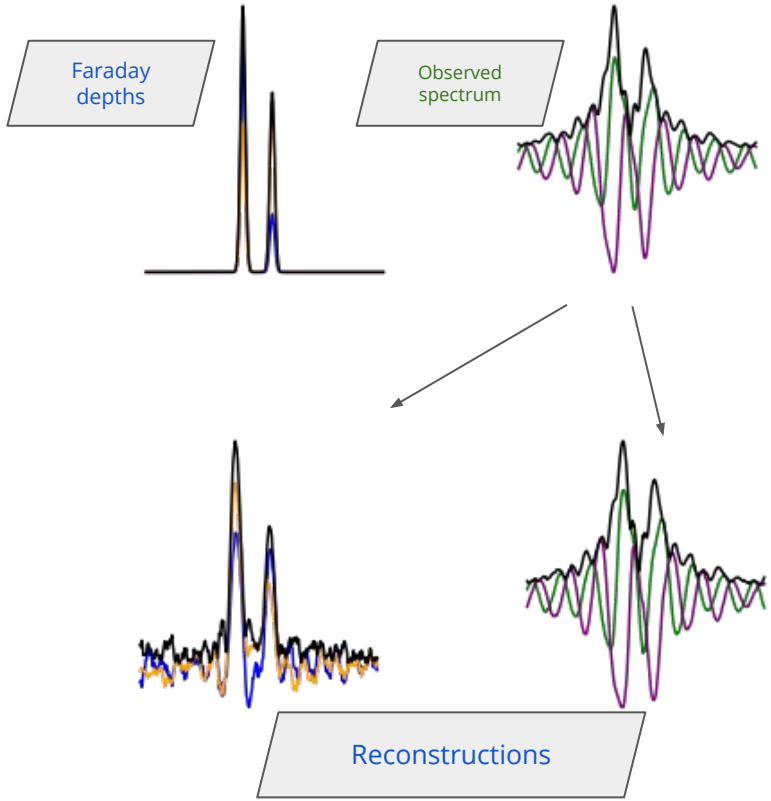


Faraday spectrum feature extractor

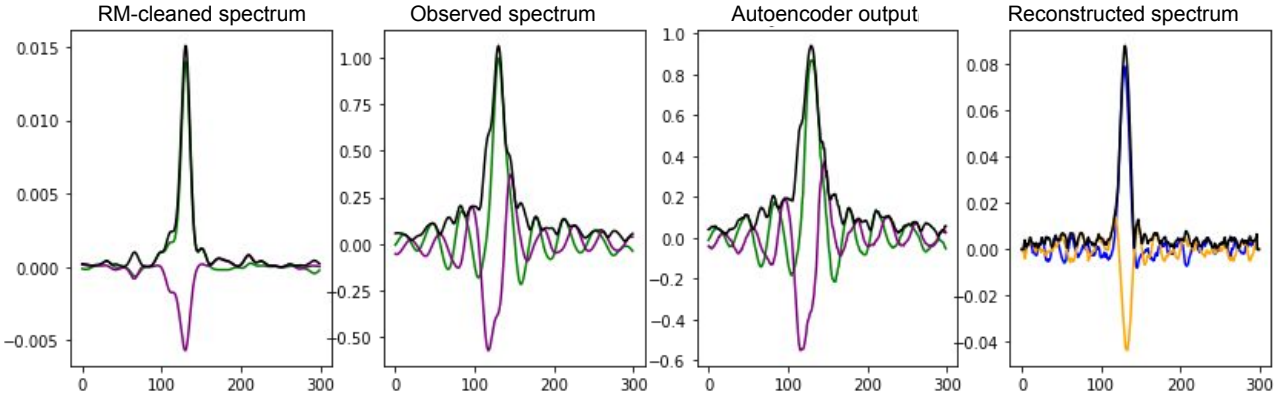


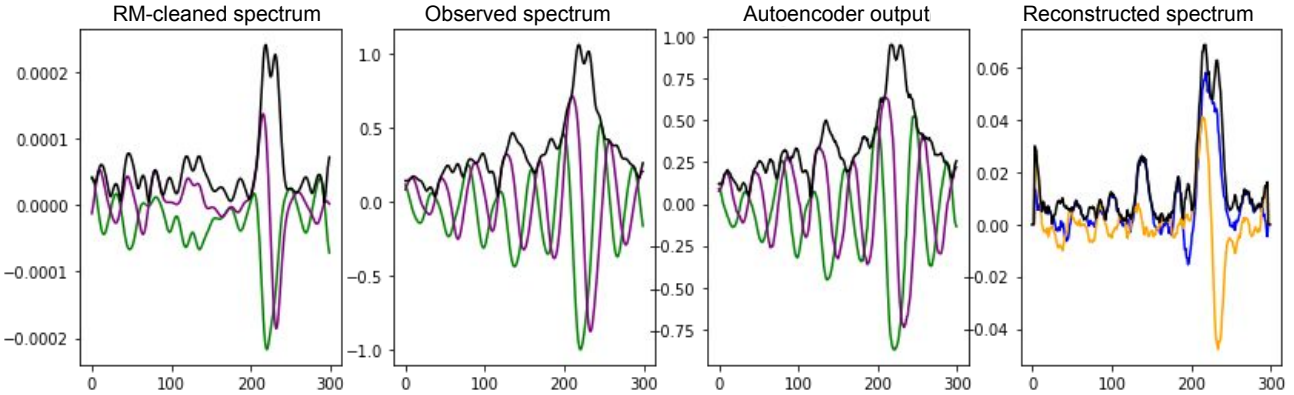
Reconstructing simulated spectra





Reconstructing real data

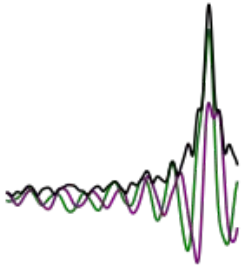


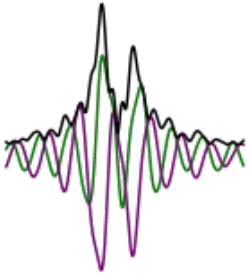


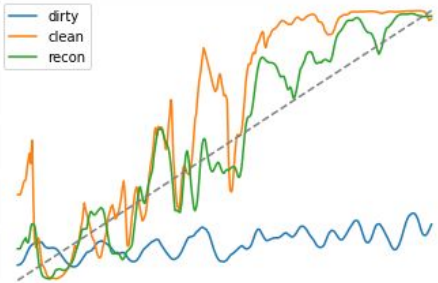
Polarised sources observed with ATCA (courtesy of Jack Livingston).

Using features: Faraday complexity

- Classify spectra as complex or simple
- Not always clear-cut
  - Spectra are noisy
  - Screens can be close together
  - Slabs may look like screens
- Linear models perform alright with latent features





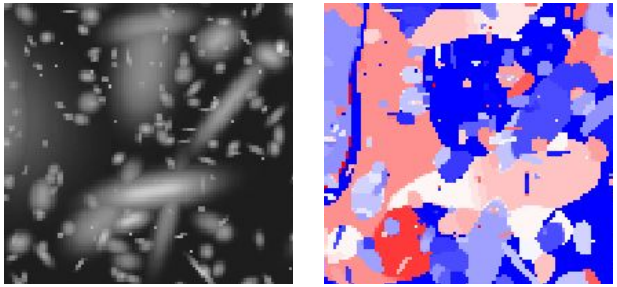


Issues and limitations

- Extremely sensitive to scale
  - Fortunately scale of *observations* so we can account for this
- Just one RMSF
  - Datasets can have multiple RMSF depending on data quality and issues
  - Different datasets have different RMSFs
  - Still pretty good reconstructions on different datasets!
- Assumes spatially independent spectra

Future work

- Generalise to range of RMSFs
- Work in three dimensions
  - Removes independence assumption
- More complicated simulated observations
- Train on POSSUM early observations



Simulated polarised sources and corresponding Faraday depths (Matthew Whiting).