Interference

Daniel Mitchell,

ATNF and Sydney University.

Overview

- **Radio Frequency Interference**

  Sources of Interference, ATCA Interference Surveys, Effect on Synthesis Images.

- **Robustness of an Interferometer**

  Bandwidth Smearing, Broadband Decorrelation, Time-Average Smearing.

- **Dealing with Interference**

  Interference Mitigation.

Radio Frequency Interference

- Most people will encounter interference when using radio data.
- Continuum Observations:

  Require wide bandwidths for sensitivity -> it's hard to find large, unoccupied portions of the radio spectrum.

- Spectral Line Observations:

  Spectral lines are often redshifted out of the protected bands.

- Pulsar Surveys:

  Interference can have similar signatures to pulsar signals.

Sources of Interference

- **Self generated Interference**

  Digital equipment at the observatory (testing, isolation & shielding)

- **Natural Interference**

  Solar interference

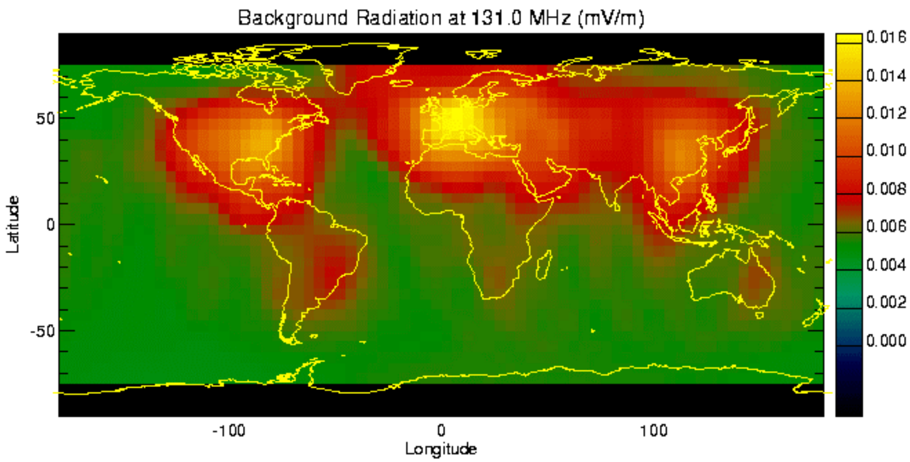
- **Terrestrial Interference**

  Build the array in a radio quiet location

- **Satellite Interference**

  Navigation satellites (GPS & GLONASS), "Low Earth Orbit" communication satellites (Iridium & Globalstar), Geostationary satellites (AUSSAT), Radar and weather satellites, etc.

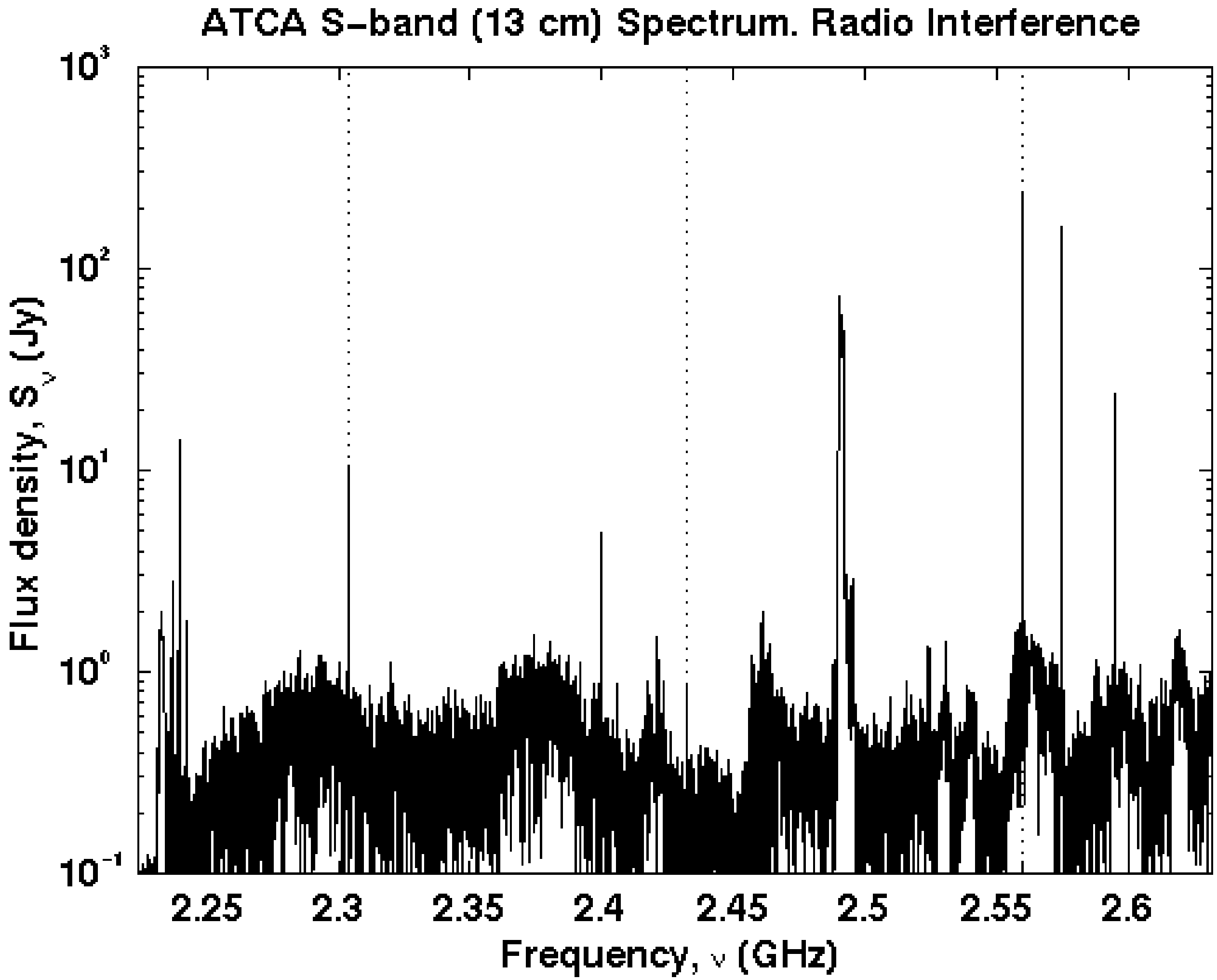
FORTÉ Satellite Map



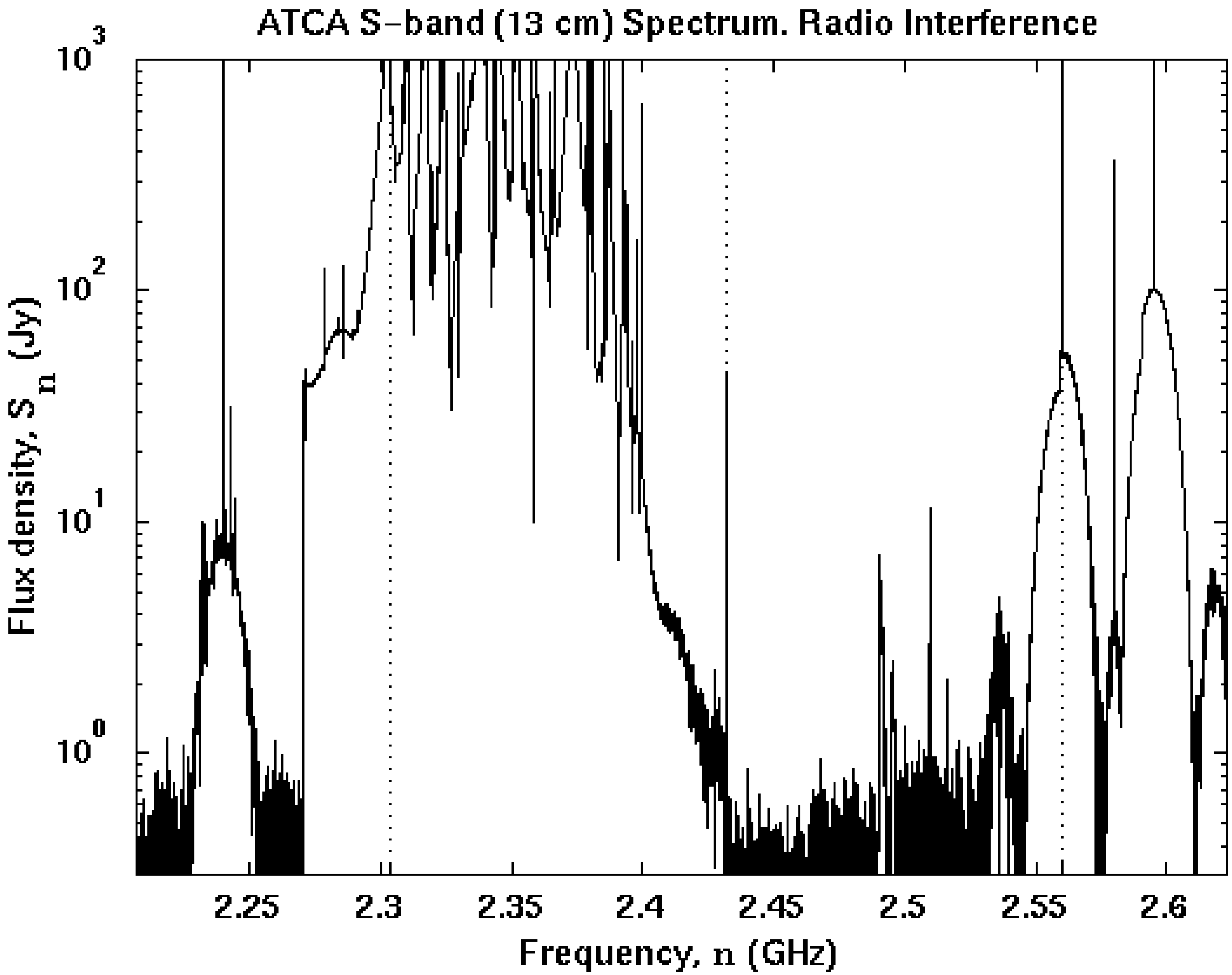
ATCA Interference Surveys

- Surveys are conducted over the four cm bands (3, 6, 13 & 20 cm): http://www.atnf.csiro.au/people/dmitchel/ATCA/
- Images and recommended frequencies given in the ATCA User's Guide
- An overview is given at: http://www.narrabri.atnf.csiro.au/operations/rfi.html

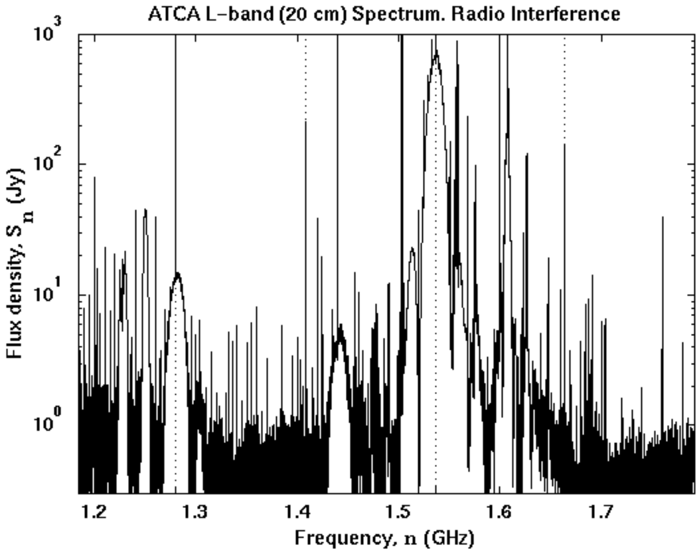
13cm, July 2002

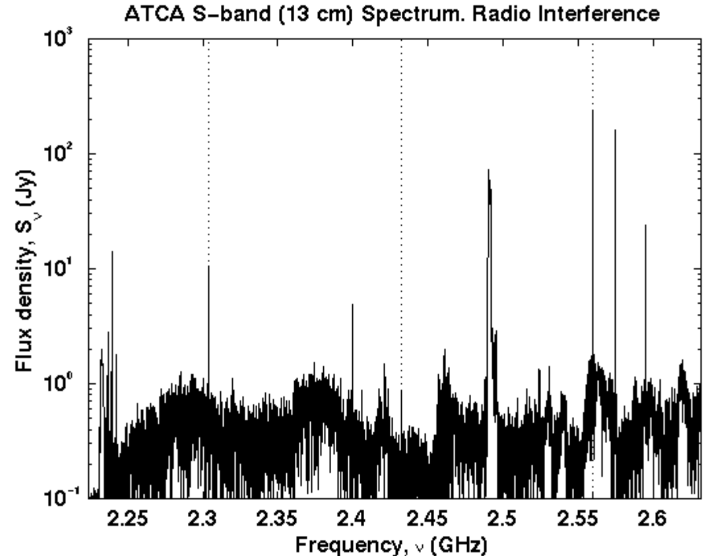


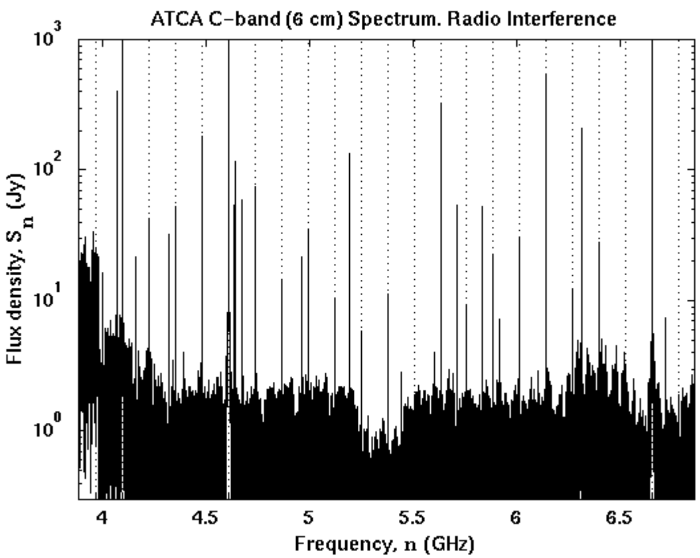
13cm, December 2001

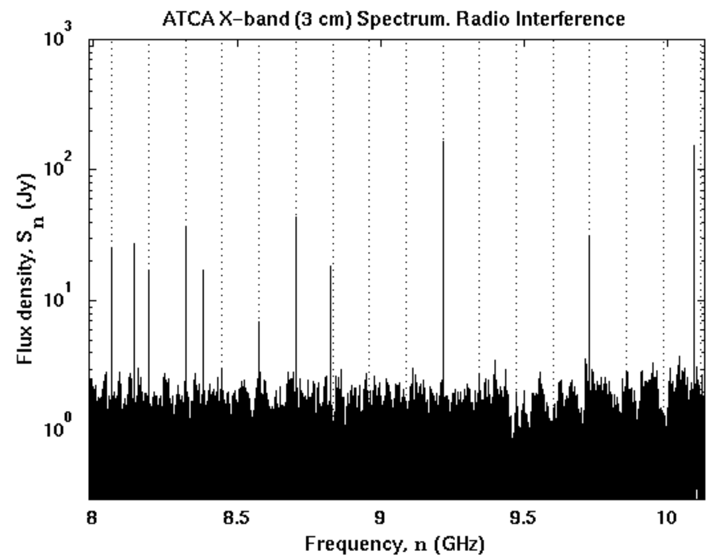


ATCA cm Bands







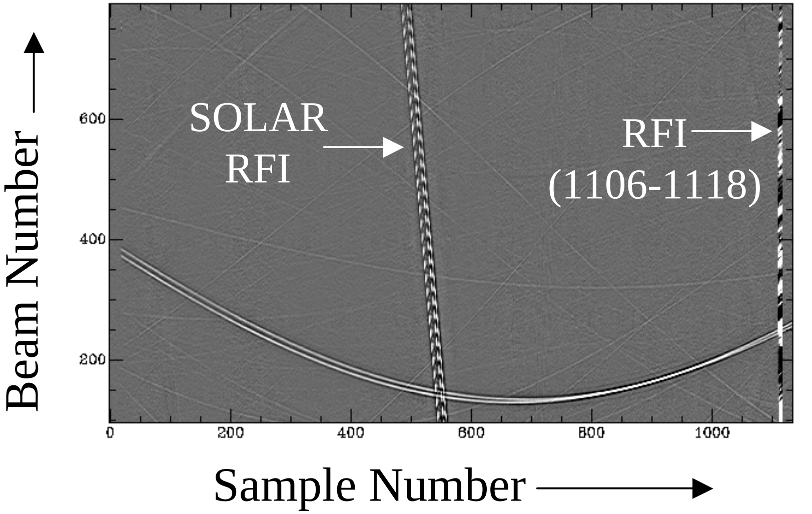


Effect on Synthesis Images

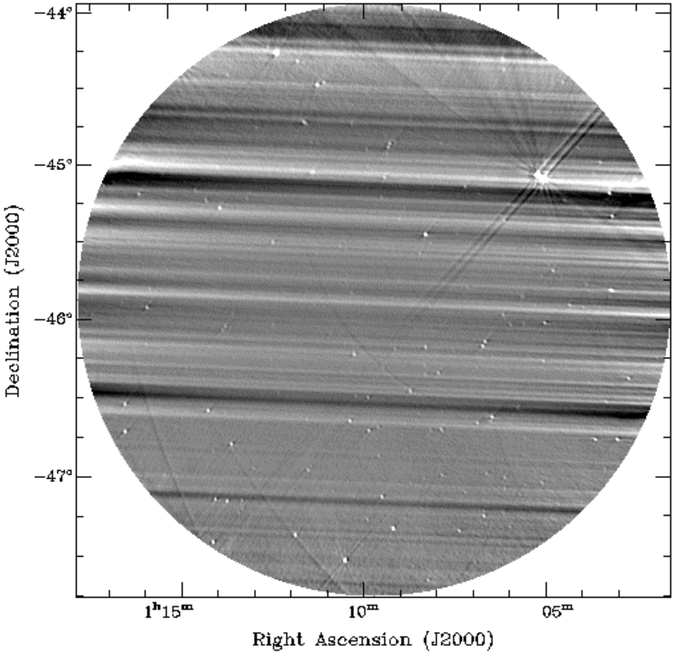
- The strength, location, duration, polarisation, etc. of an interfering signal have various effects on the final image.

- Interference enters the visibilities, so it’s the Fourier transform that is seen in the image

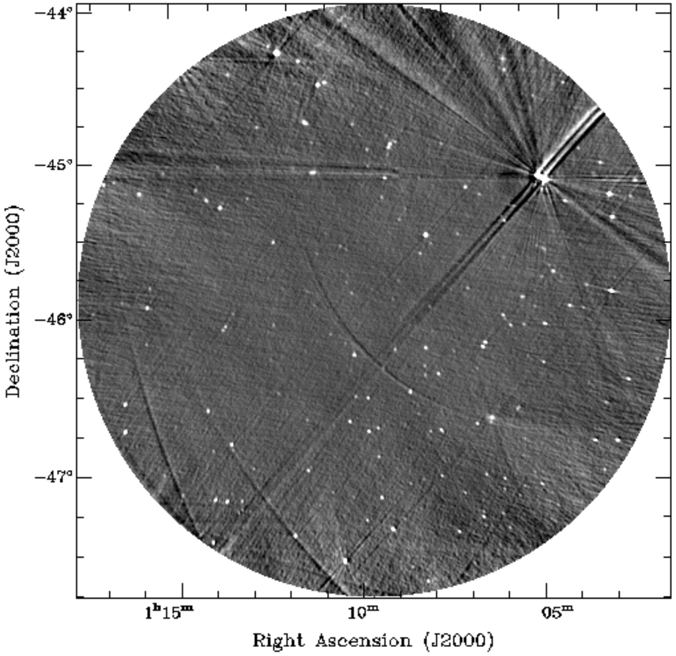
MOST Interference



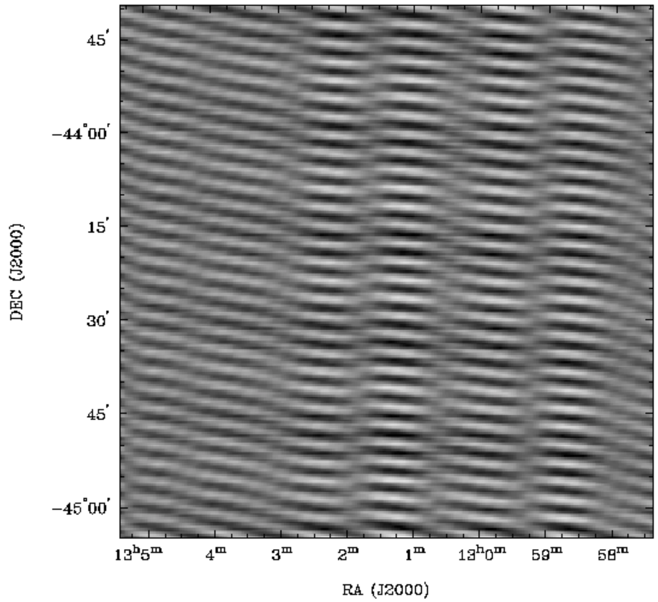
All 1134 Samples Used

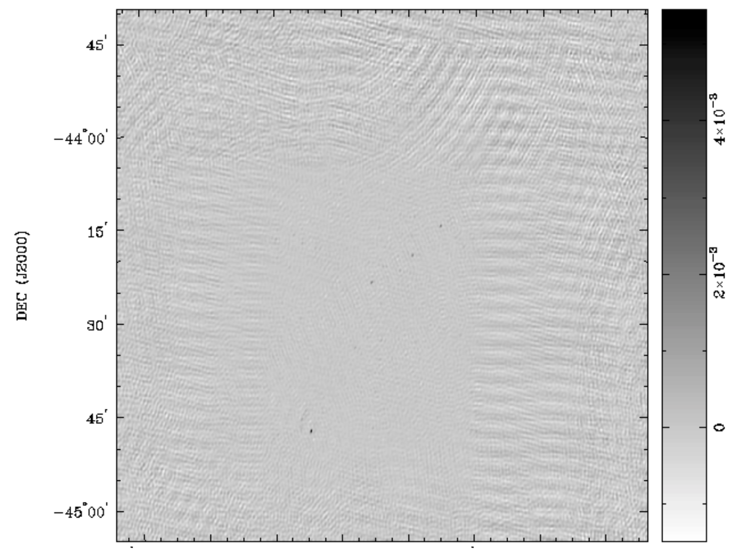


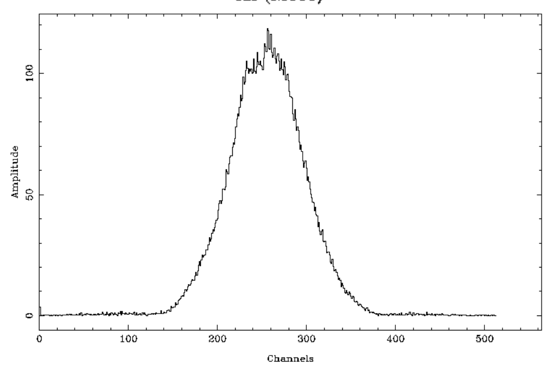
Samples 1106 – 1118 Ignored

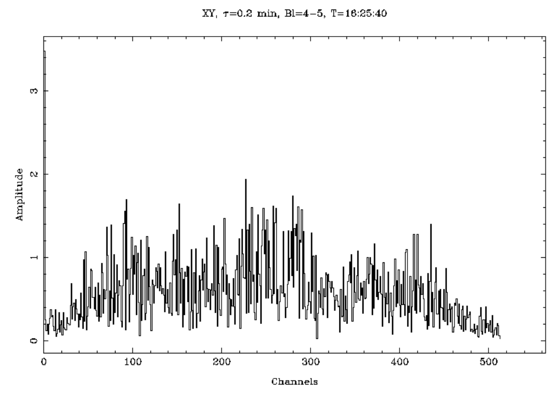


ATCA Interference (microwave link)





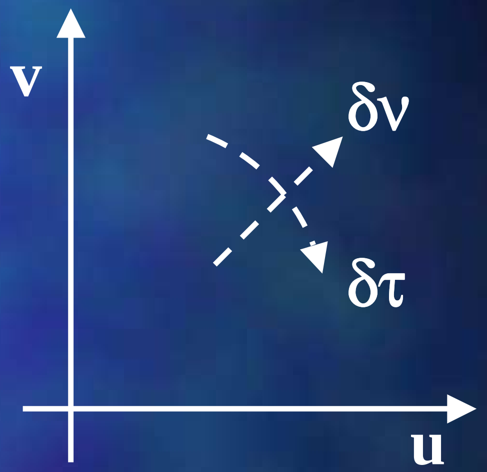




Images made by M. Kesteven.

Robustness of an Interferometer

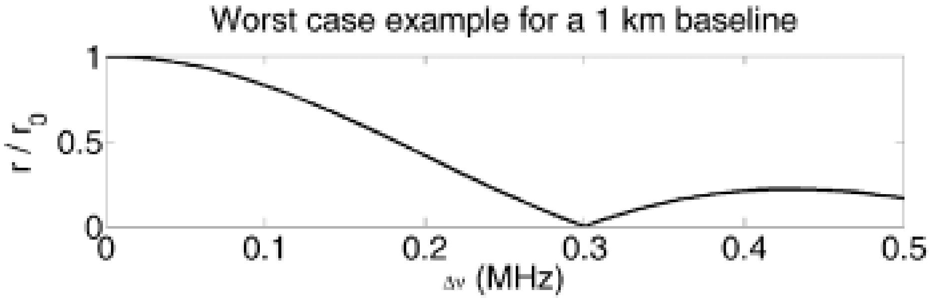
- Interferometer's have added protection against RFI compared with single dishes.
- Extra decorrelation of the RFI occurs in both the time and frequency domains.



Bandwidth Smearing

- Visibility locations are functions of wavelength.
- Different monochromatic components of a broadband signal experience different phase shifts as a wavefront travels between antennae.
- The effect is a radial smearing in the uv-plane => radial smearing in image.

The ideal response of the correlator, V(ν_0), is reduced as the bandwidth, $\Delta\nu$, and the time delay, τ_g, increase.



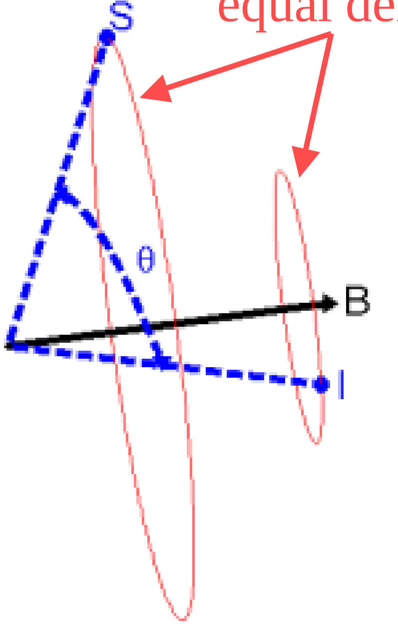
$$V'(\nu_0) = \int_{\nu_0-\Delta\nu/2}^{\nu_0+\Delta\nu/2} V(\nu)\,d\nu = \left|\mathrm{sinc}(\Delta\nu\,\tau_g)\right| V(\nu_0)$$

§2.3, §2.11, §17.1.1, §18.1.

Broadband Decorrelation

- Antenna delays are set so that a wavefront from ***s*** reaches the correlator via each antenna at the same time.
- An interfering signal, ***i***, with a different delay will suffer bandwidth smearing.
- The correlater output r_0 will be reduced quickly as ***i*** moves away from the field centre.

Circles on the celestial sphere of equal delay



$$V'(\nu_0) = \left|\mathrm{sinc}(\Delta\nu\tau_d)\right| V(\nu_0)$$

were the time delay of the interfering signal, τ_d, is

$$\tau_d = \frac{D\left|\sin\theta\right|}{c}$$

§2.3, §2.11.

Time-Average Smearing

- Variable delays and phase shifts are inserted to track the celestial sphere
- Signals not moving with the celestial sphere will move through fringes.
- The effect is tangential smearing in the uv-plane => tangential smearing in image

The ideal response, $V(\tau_i(t_0))$, is reduced as the frequency, ν_0, and the change in delay, $\Delta\tau_i$, increase.

$$V'(\tau_i(t_0)) = \frac{1}{\tau_A} \int_{t_0 - \frac{\Delta t}{2}}^{t_0 + \frac{\Delta t}{2}} V(\tau_i(t))dt$$

$$= \left|\mathrm{sinc}(\nu_0 \Delta\tau_i)\right| V(\tau_i(t_0))$$

For terrestrial sources, the effect is opposite to what the astronomy would experience if fringe stopping isn't implemented.

$$r = \left|\mathrm{sinc}(\nu_f \Delta t)\right| r_0$$

$$\nu_f = \omega_e u \cos(\delta)$$

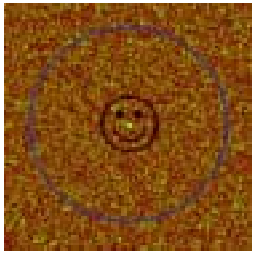
§2.4, §2.12 §17.1.2, §18.2.

Dealing with Interference

- Further measures can be taken to reduce unwanted signals
- Some examples include removing / reducing the interference at the source, choosing a better location / frequency / time, using more robust statistics, time and frequency filters, flagging data, interference mitigation

Interference Mitigation

- A range of extremely promising algorithms are currently being demonstrated: http://www.atnf.csiro.au/SKA/intmit/
- Adaptive filtering and post-correlation cancelling.
- Moving the nulls of the interferometer pattern around (Geoff Bower's images).



- Project out strong correlated parts of the complex visibilities (sub-space techniques).
- Parametric techniques.
- The decorrelation effects mentioned on previous slides must be taken into account.

Summary

- Increased use of the spectrum and more sensitive instruments will make interference worse in the future.
- Interferometers have built-in mechanisms which help to reduce the interference.
- Many of these mechanisms are more effective on long baselines.
- A lot can be done by designing equipment and planning observations carefully.
- As new instruments are built and current instruments upgraded, new algorithms are being implemented to mitigate the interference.