

RFI:  
Astronomical Considerations

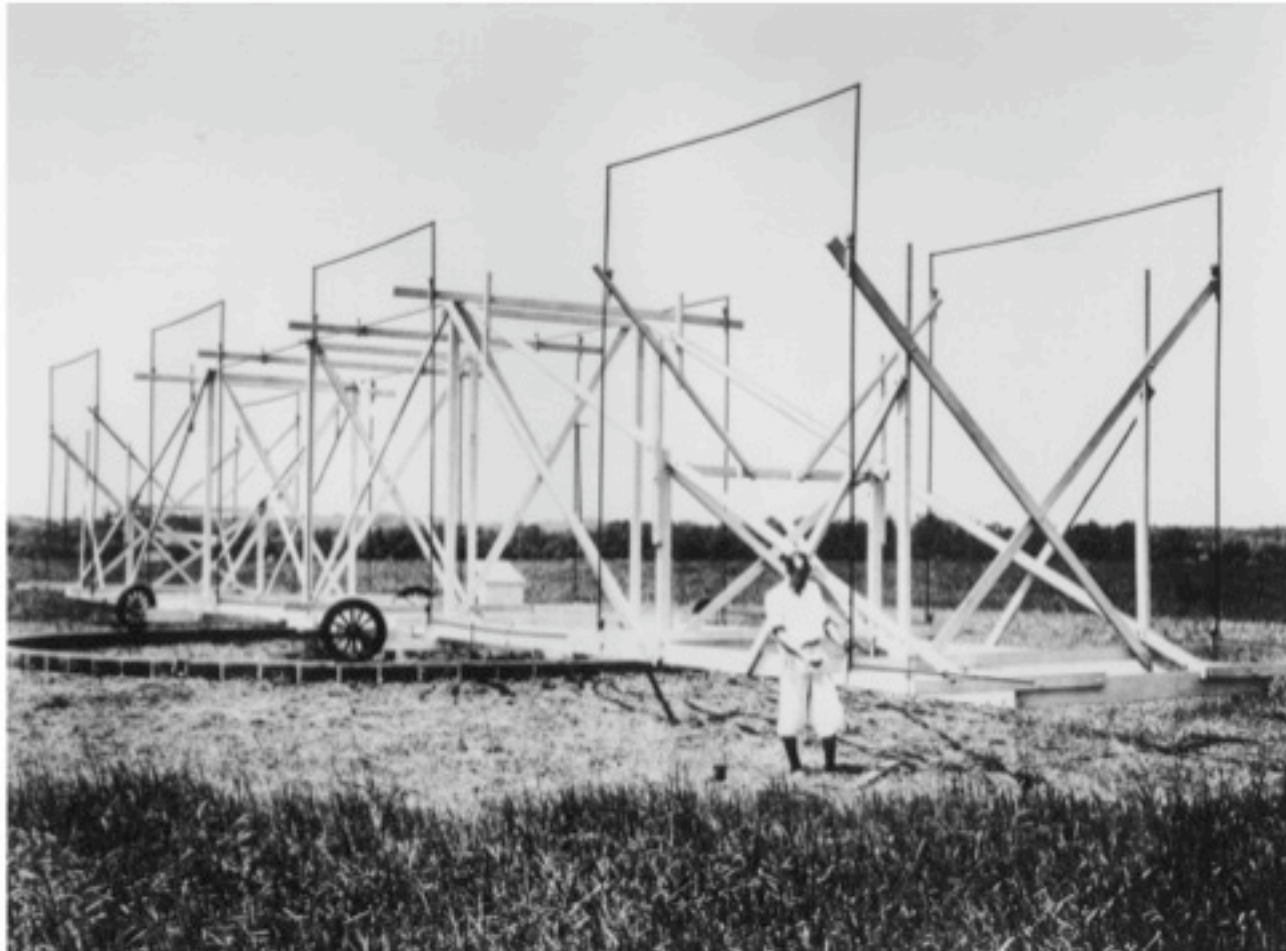
Phil Edwards (CSIRO ATNF)

# RFI

- Radio astronomers make passive use of wide spectral bands, extending beyond the much smaller bands allocated for passive use (mostly) in order to improve the sensitivity of their observations
- These bands inevitably (and increasingly) carry legally licensed transmissions, which are typically much stronger than the astronomical signals

rfi

# The beginnings of radio astronomy



“If not for RFI, there would be no radio astronomy”?

# Jansky

- Jansky, working for Bell Labs, was searching for sources of interference affecting trans-Atlantic radio-communications and concluded there were three classes of interference
  - Local thunderstorms
  - Distant thunderstorms
  - A steady background hiss

# Optical Interference

- Rapid oscillations in cataclysmic variables. III - an oblique rotator in an AE Aquarii  
Patterson, J., 1979, ApJ, 234, 978
- Discovery of a periodic oscillation in the light-curve with a period of 33.076737s
- “However, one night’s data were rejected because of contamination by fireflies (= lightning bugs). It was found that West Texas fireflies tend to emit pulses at ~15 s intervals on warm nights in July.”

# Grote Reber



# Reber

- Inspired by Jansky's work, Reber built a radio telescope in his backyard in Chicago. One of his first discoveries was of man-made RFI – from cars.
- To minimise the impact of this RFI on his observations, Reber observed at night.



Parke  
may  
have  
Elvis...



...but Narrabri has Santa!

THE COURIER  
*Good news for Virginia...*  
**Santa 'sighting' by  
Australia Telescope?**

by Benn Marks

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*Good news for Virginia...*

**Santa 'sighting' by  
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A case of scientific credibility at Narrabri-based Australia Telescope on Christmas Eve may just be the scientific confirmation millions of children (the world's most famous Santa list) are waiting for.

It may be familiar with the editorial written by Francis & Co in the New York Times in 1957 and in the following letter to the

8 years old. Some of my little say there is no Santa Claus, etc. "If you see it in The Sun, Please tell me the truth, is a Santa Claus?" Virginia

has gone on to become an enormous success to the end of Santa Claus which has been all every year since. Country can now reveal, in a list, the CSIRO Radio Telescope unit at Narrabri has picked up signs to be unambiguously identified as the existence of the legend bearing figure.

Further analysis and statistics the signal - or "sighting" as it's only referred to in scientific circles - was evident that of Santa's

The event is clearly recorded on the observing log shown below.

A CSIRO Radio Telescope spokesman said the discovery had started away in the scientific community, and would certainly stay the broader community once it was published.

"It's a tremendous discovery and yes, it means Santa Claus really does exist!"

"We're thrilled and it just goes to show how incredibly powerful and useful this scientific facility is to NSW, Australia, and the world."

He also said despite the fact that the facility's program may never be general to appear along the same lines as a conventional search radar, it is able to measure Santa's sleigh's trajectory, velocity and payload from the data.

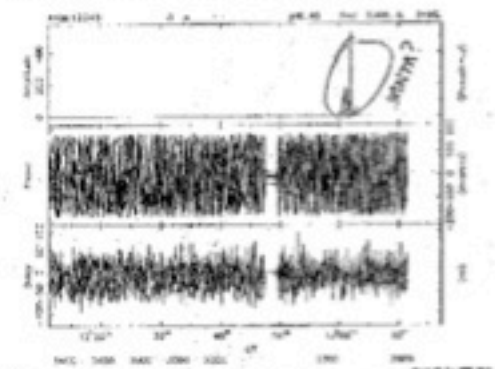
The spokesman will certainly beady admitted both the speed and payload of the sleigh "was immense", despite the information will being classed as "highly classified".

He said the discovery had been "top secret" for the past two weeks while the signal underwent further analysis.

There is no doubt that the discovery of Virginia and the sightings will be placed about the new evidence for Santa.

That the signal exists in terrestrial and only occur in Narrabri would suggest observations other than Mr. Claus' high speed sleigh, things such as a transient radio signal from an outside source, a satellite going overhead, or an unexplained data dump that only appears each year.

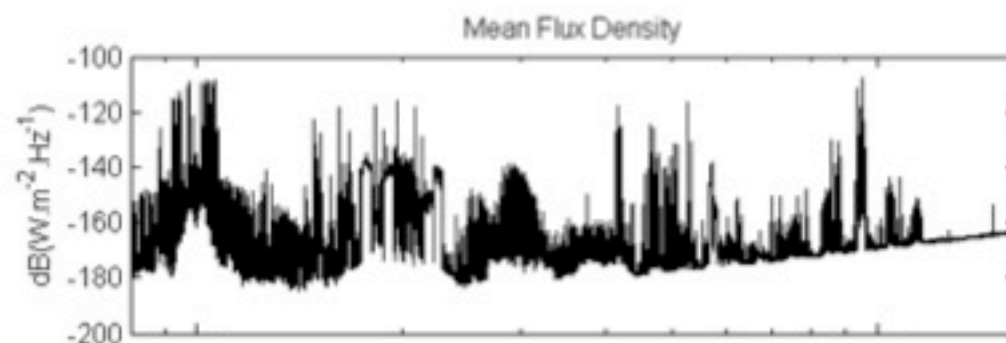
Below: The unmistakable "signal" detected by the CSIRO Radio Telescope Unit west of Narrabri at midnight, Christmas Eve.



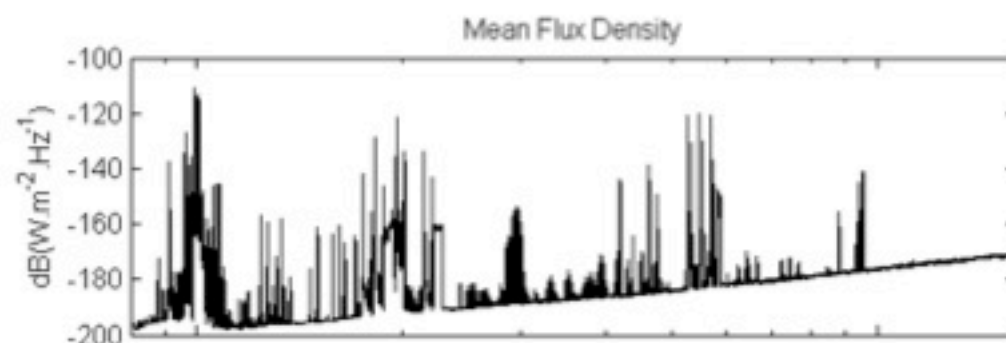
# RFI and telescope location

- Why is the Parkes telescope at Parkes?
  - To avoid RFI closer to Sydney
- Why is the ATCA at Narrabri?
  - In part, to avoid the risk of increased RFI at Parkes
- Why will ASKAP be in WA?

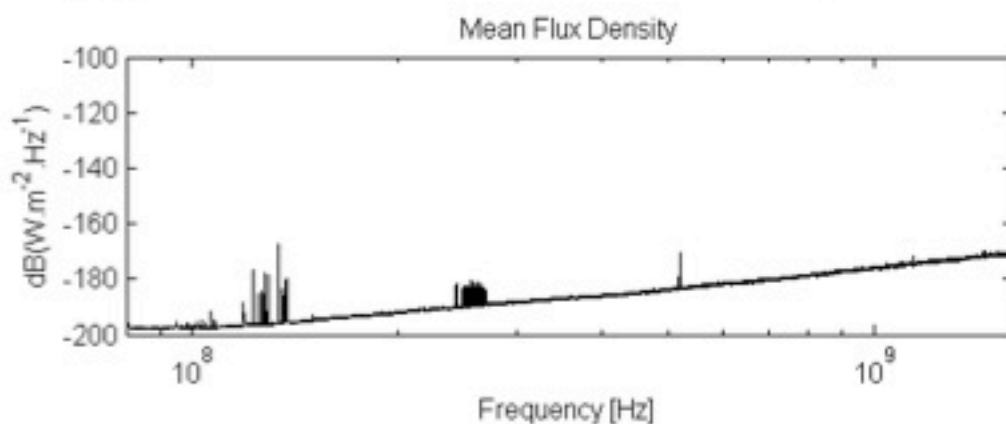
# RFI and population density



Sydney:  
population 4 million

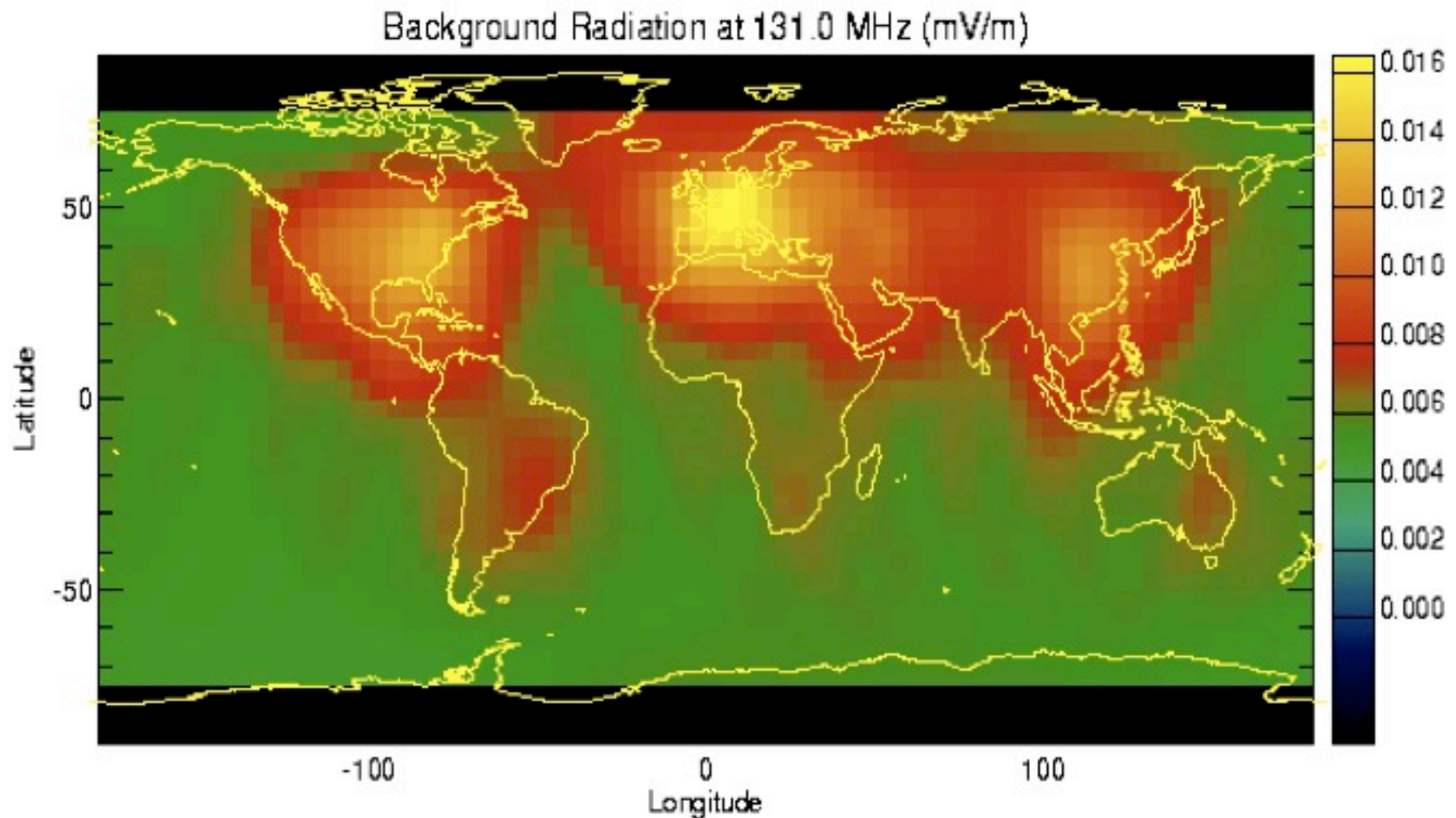


Narrabri:  
population 4000



Mileura:  
population 4

# Where are the Quiet areas?



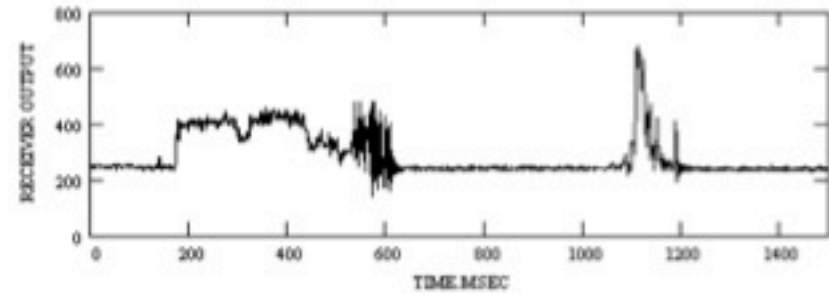
**Fast On-orbit Recording of Transient Events (FORTE) satellite**

# What are the sources of RFI?

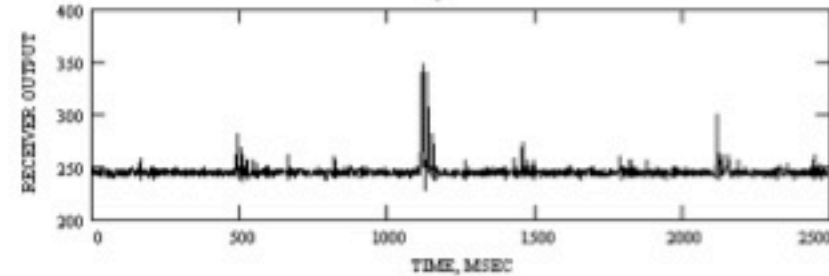
- Natural sources: Sun, lightning
- Self-generated RFI: from synthesisers, digitisers, fast electronics...
- Locally generated: wifi, microwave ovens, mobiles phones, video cameras
- Fixed transmitters: TV, communications, radar
- Mobile transmitters: communications
- Satellites: positioning systems, communications

# Types of RFI

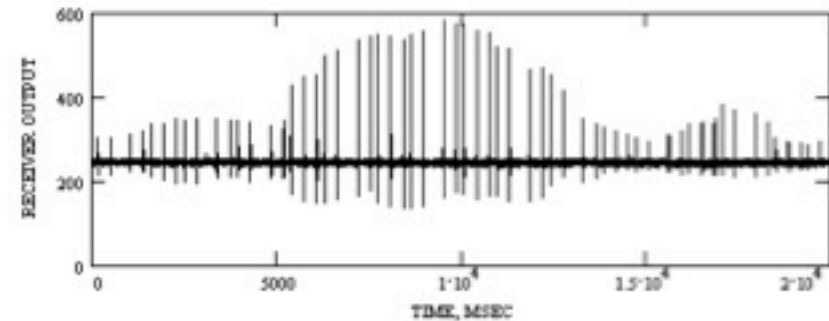
- Impulsive
- Radar pulses
- Continuous narrow-band



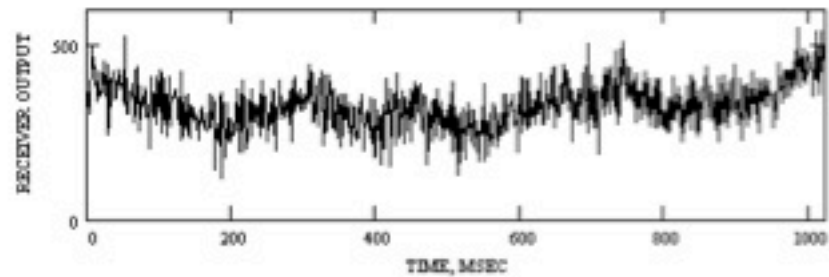
a)



b)

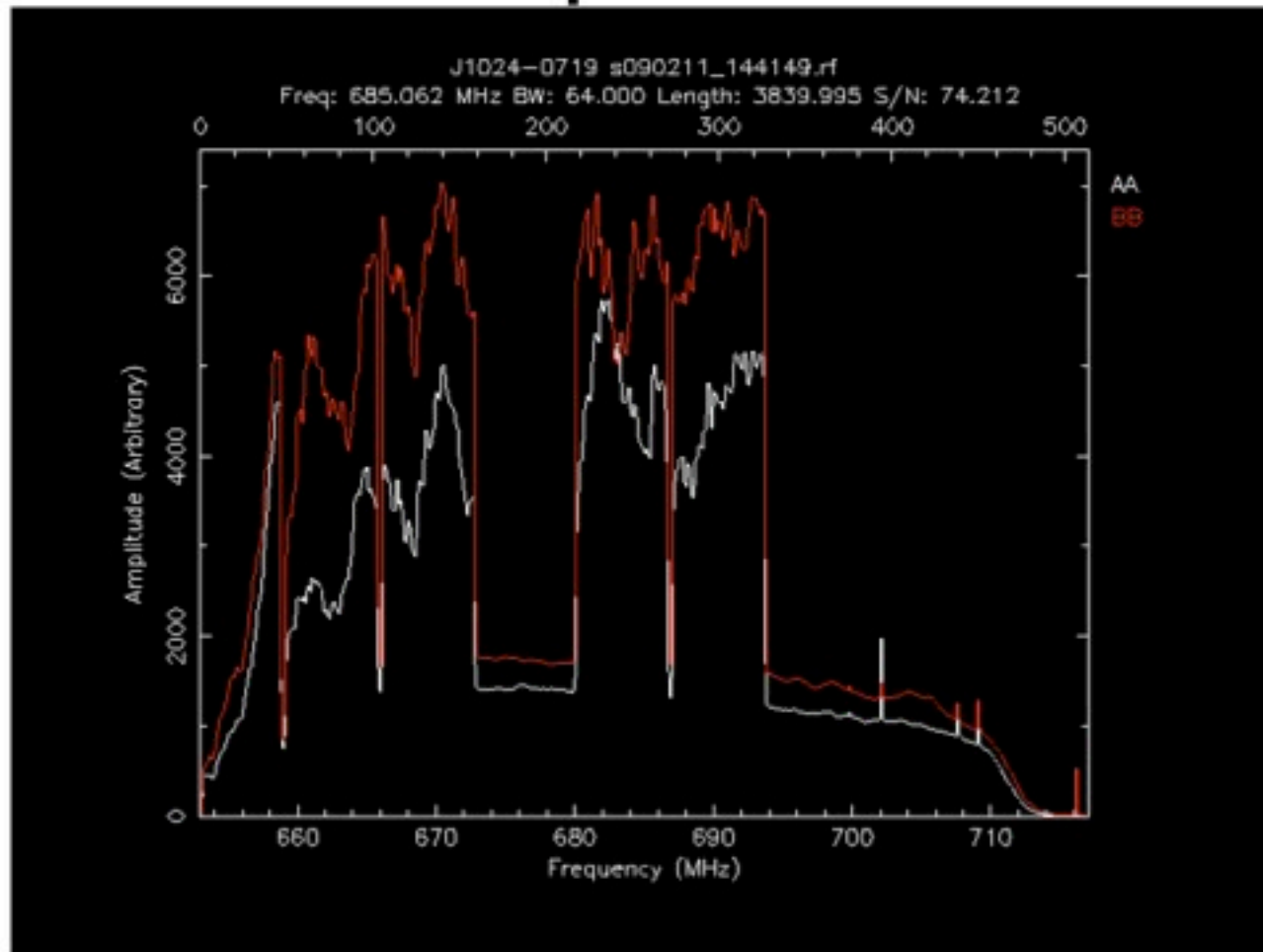


c)



d)

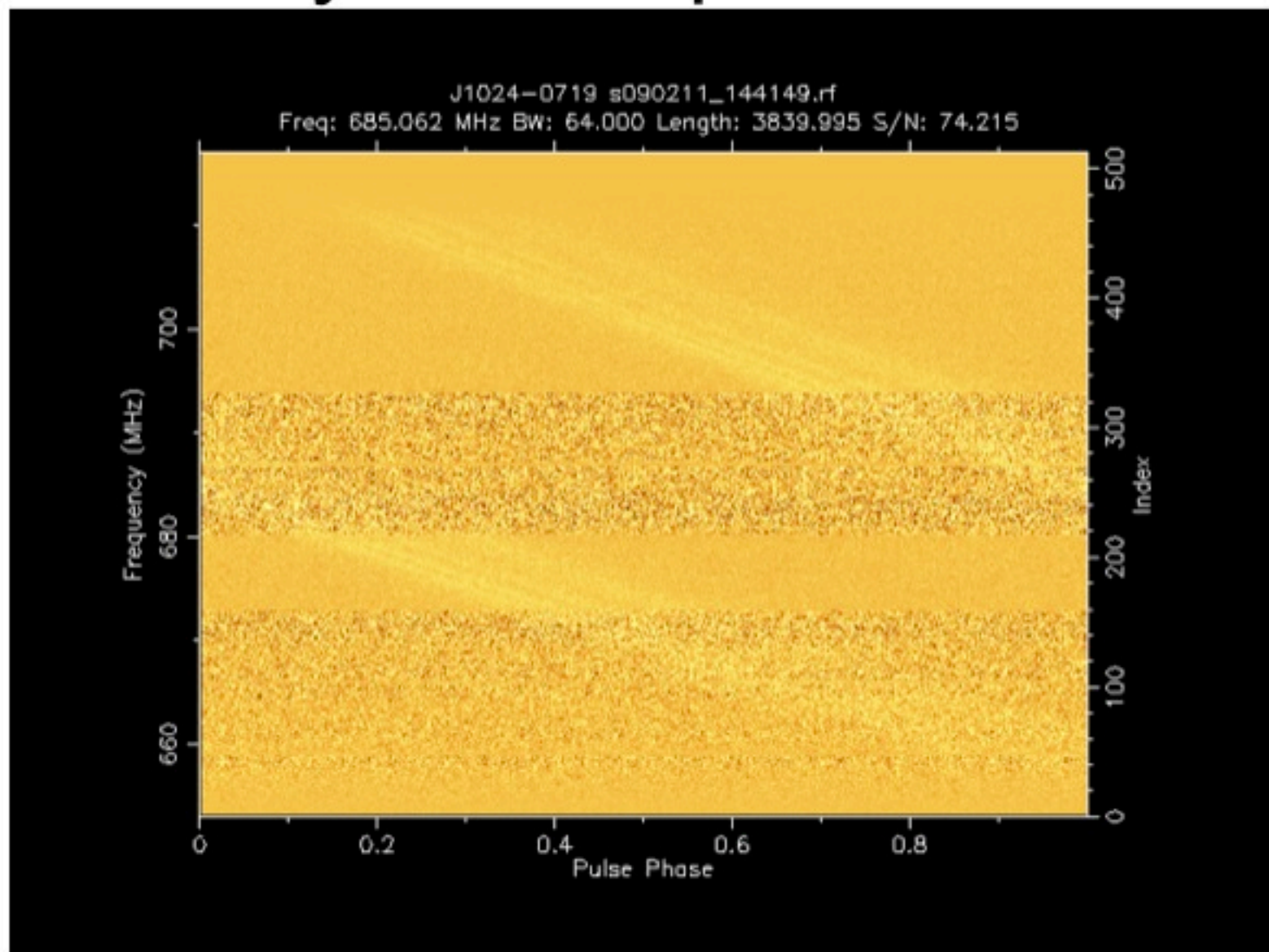
# Parke's pulsar data



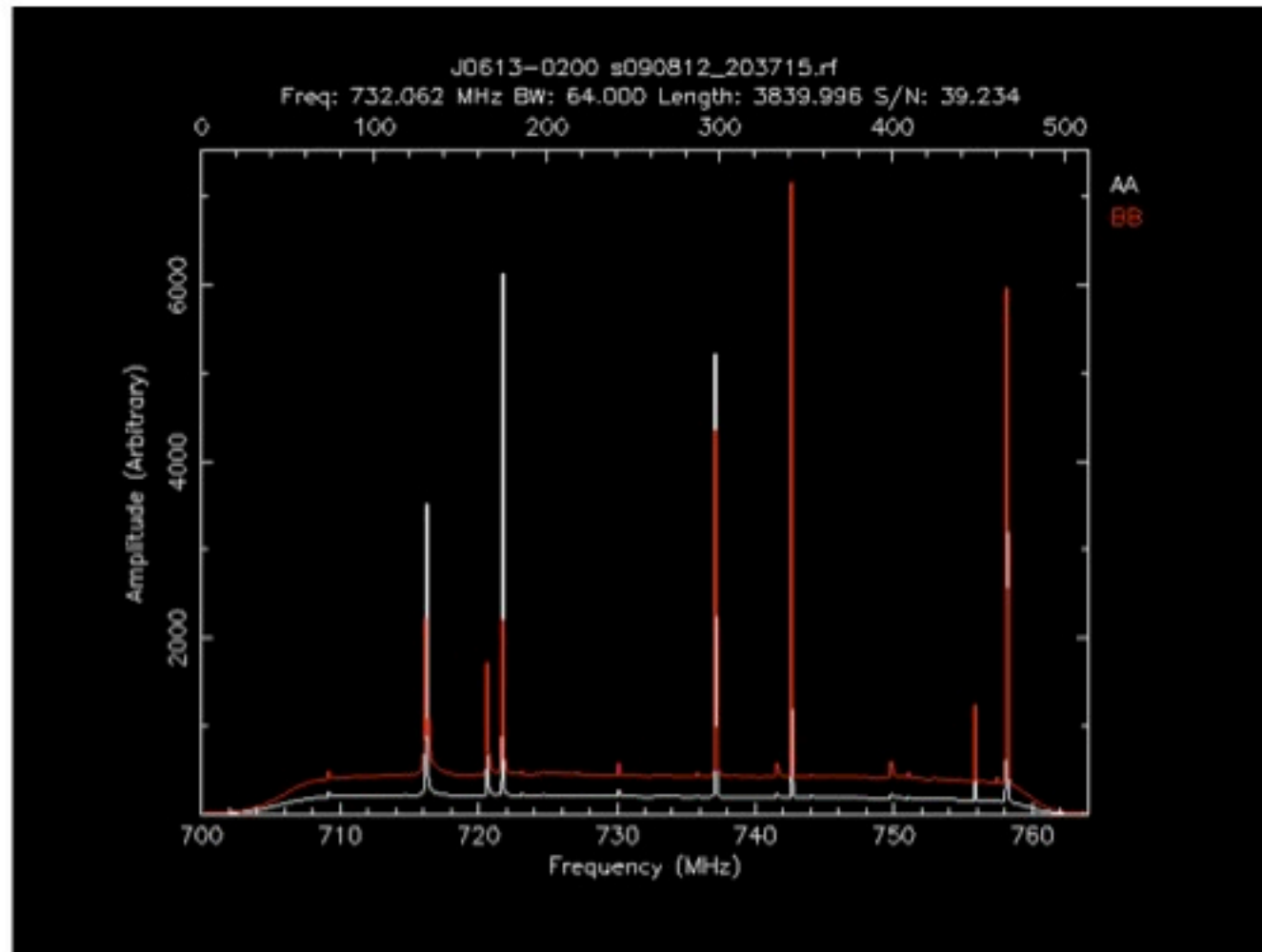
- The old 50cm band (courtesy Dick Manchester)



# Dynamic spectrum

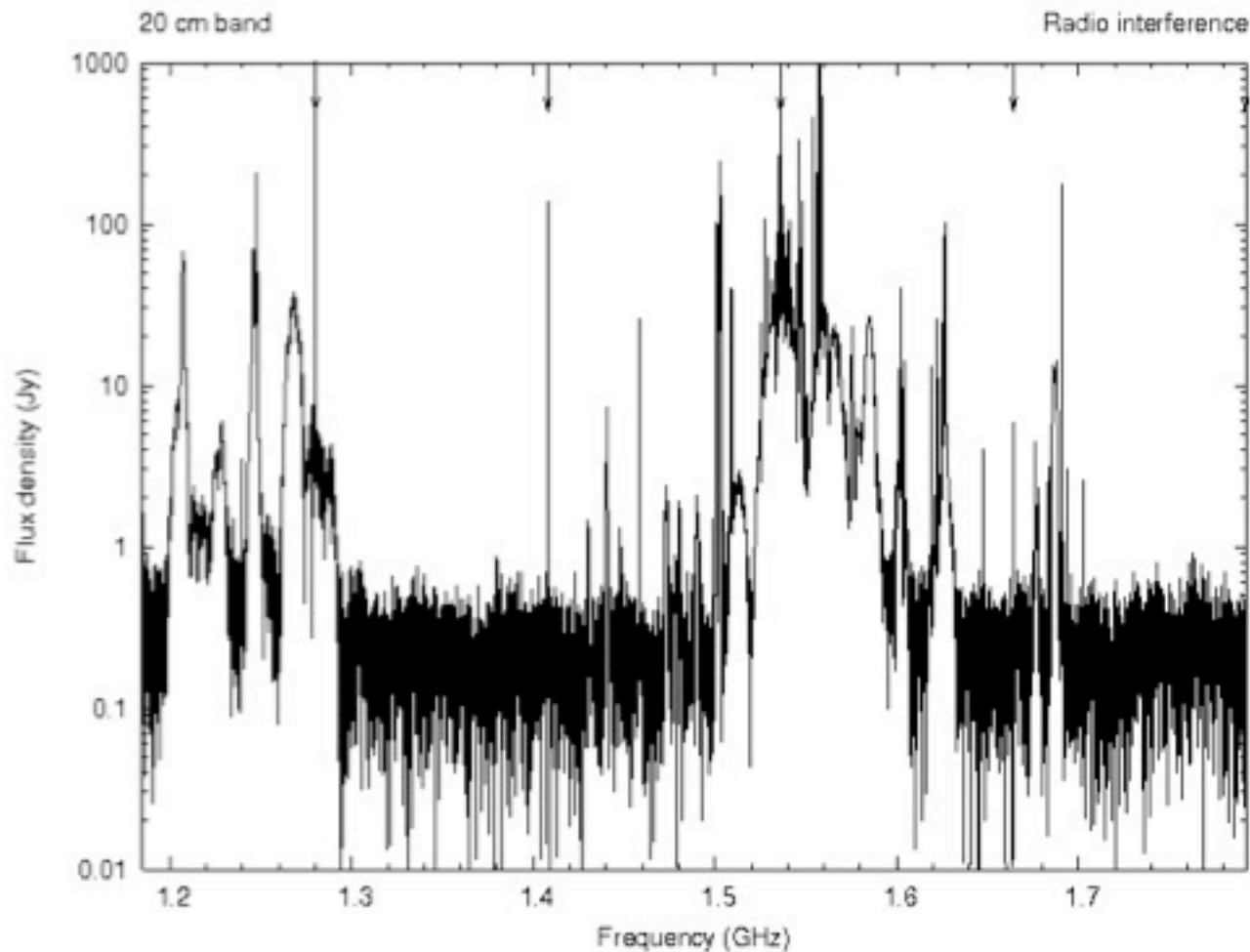


# Parke's pulsar data



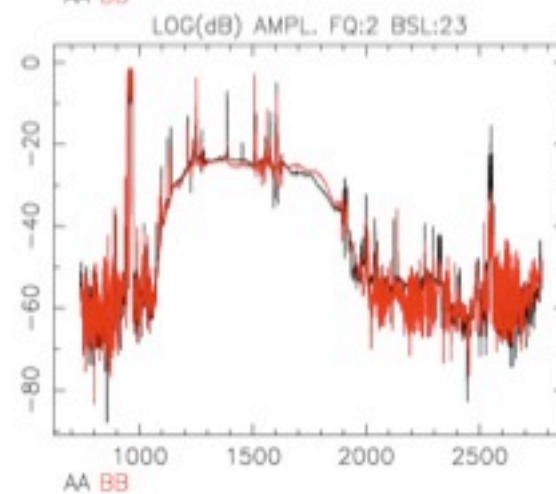
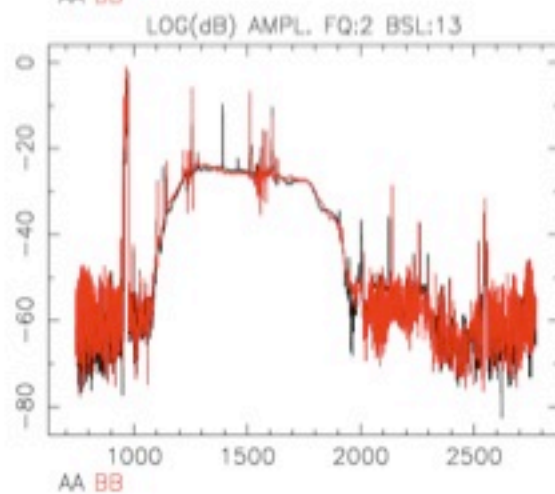
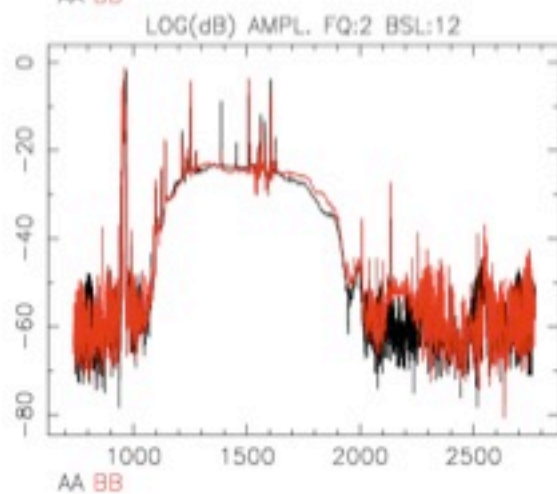
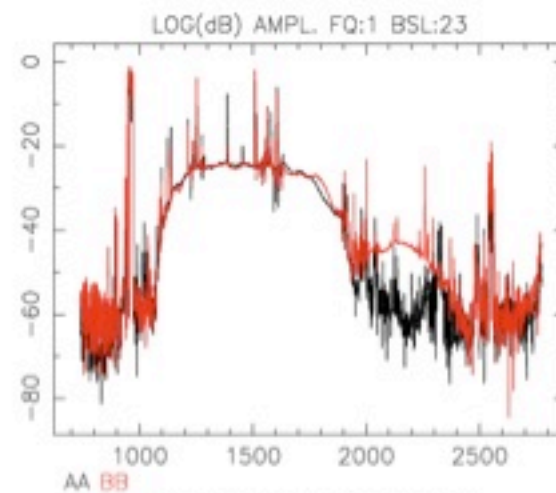
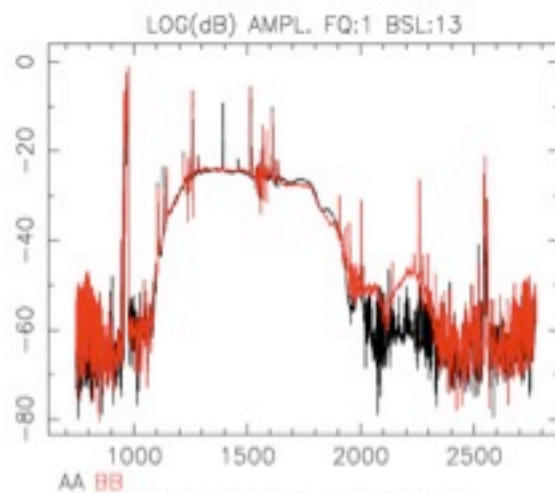
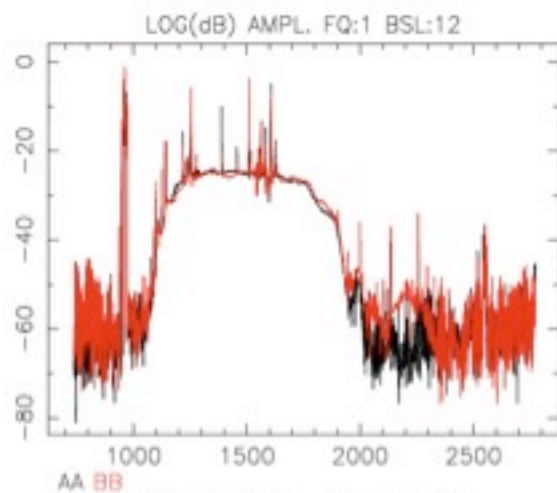
- The upbanded 50cm band, courtesy Dick Manchester

# ATCA 20cm (pre-CABB)

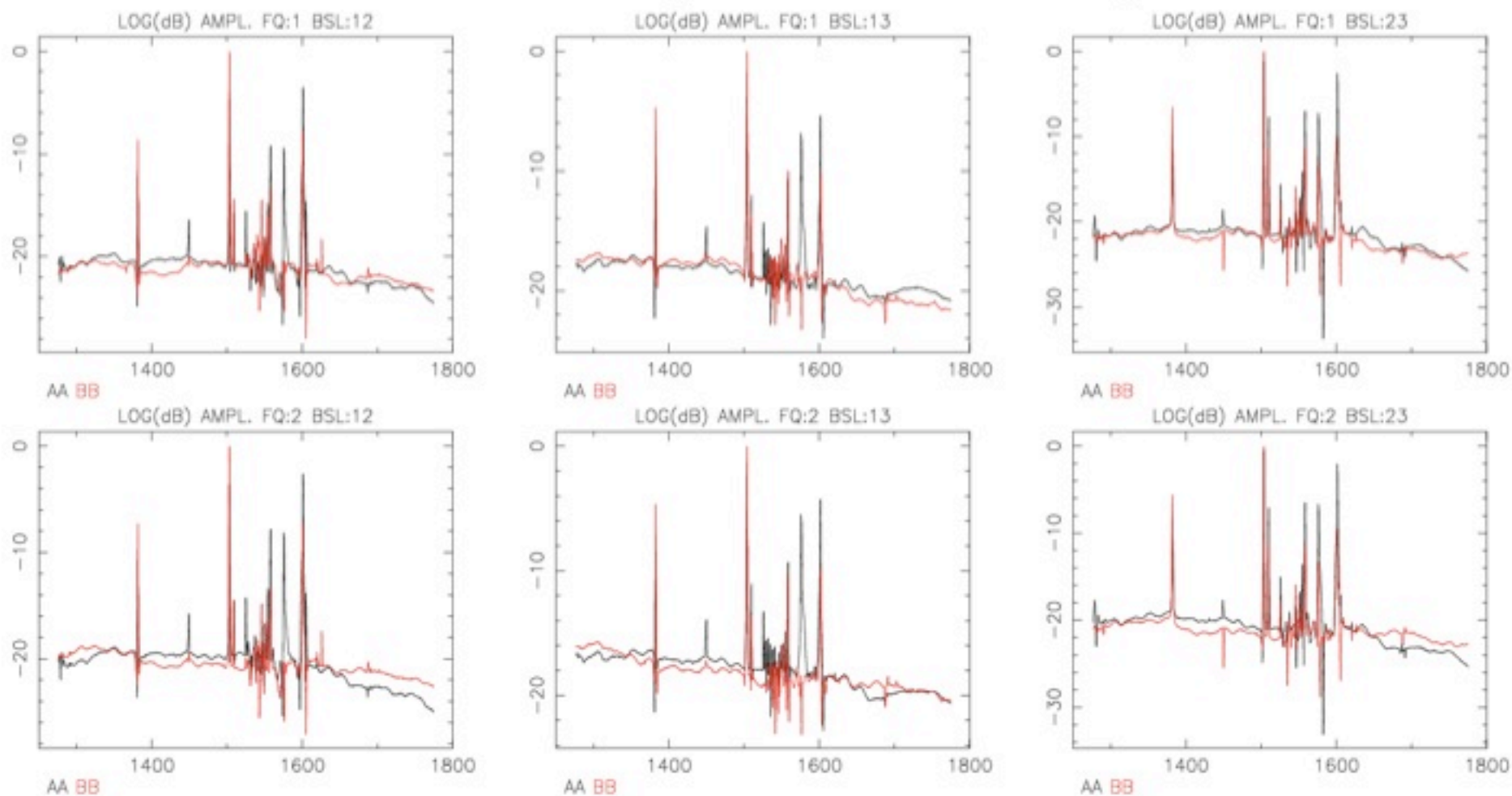


Standard observing frequencies determined by “clean” part of spectrum

# ATCA (CABB era)

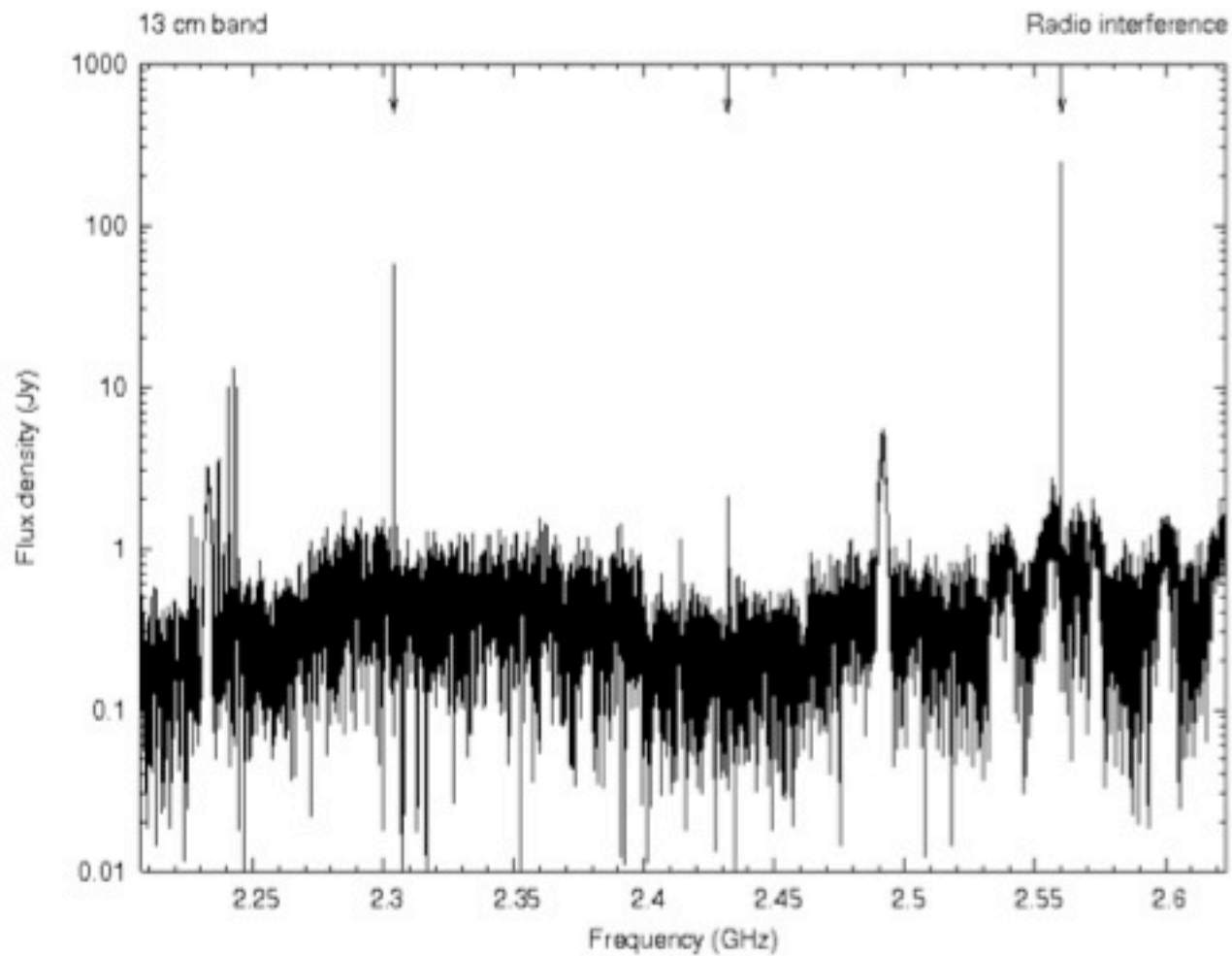


# ATCA (CABB era)

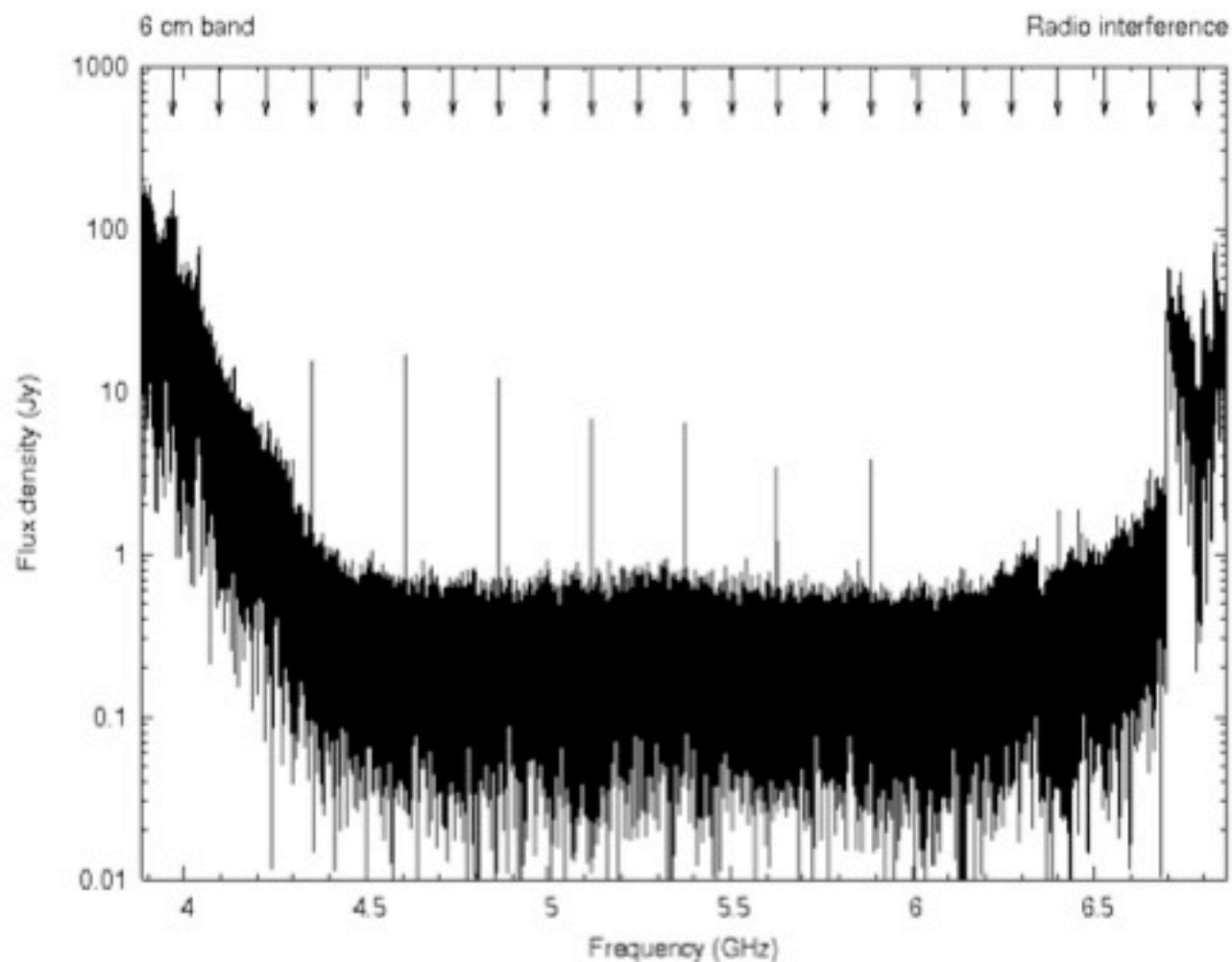


Need to set tvchan carefully before delay calibration in 20cm band

# ATCA 13cm (pre-CABB)

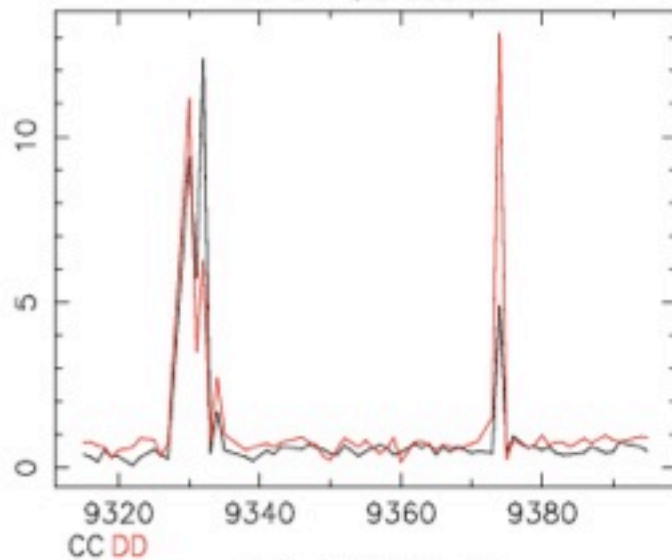


# ATCA 6cm (pre-CABB)

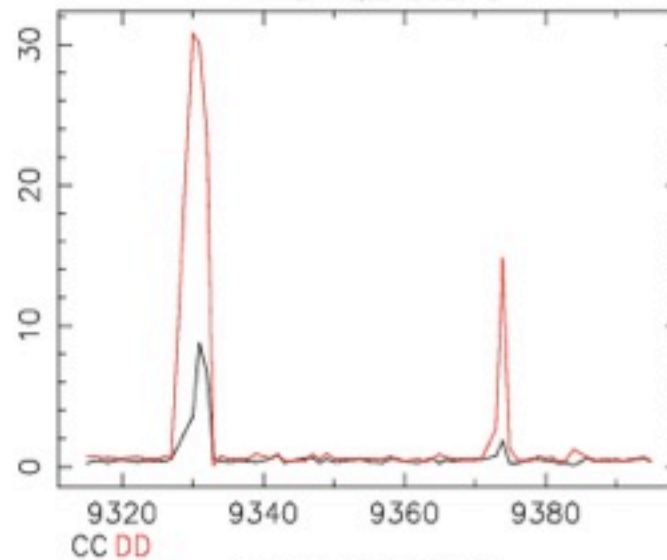


# ATCA (CABB era)

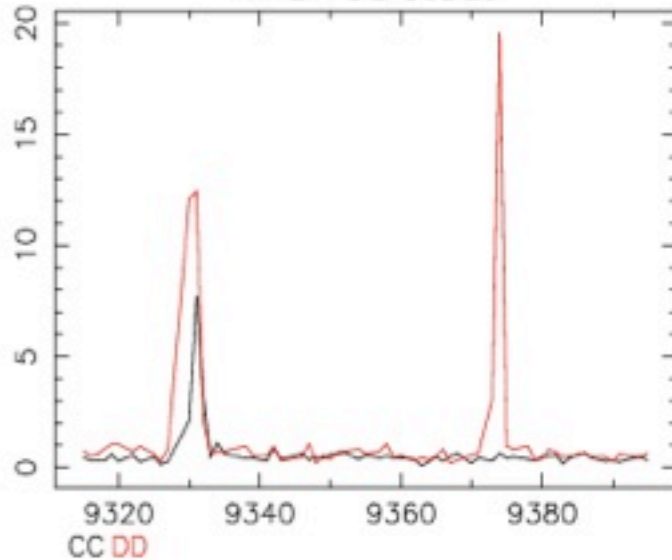
AMPL. FQ:2 BSL:12



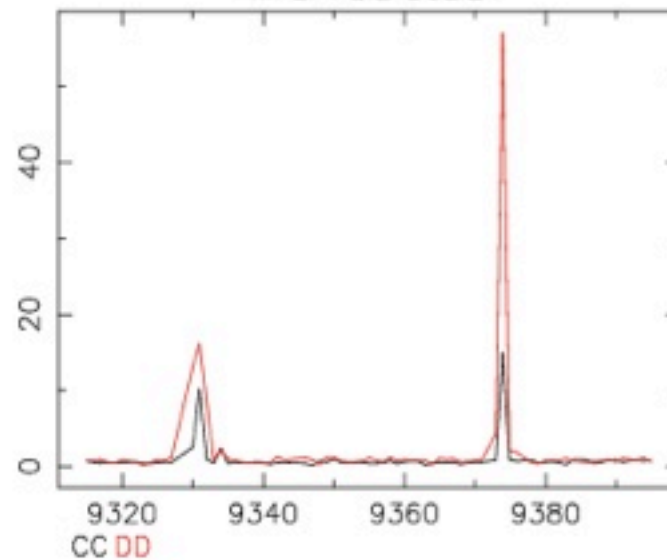
AMPL. FQ:2 BSL:13



AMPL. FQ:2 BSL:23



AMPL. FQ:2 BSL:24



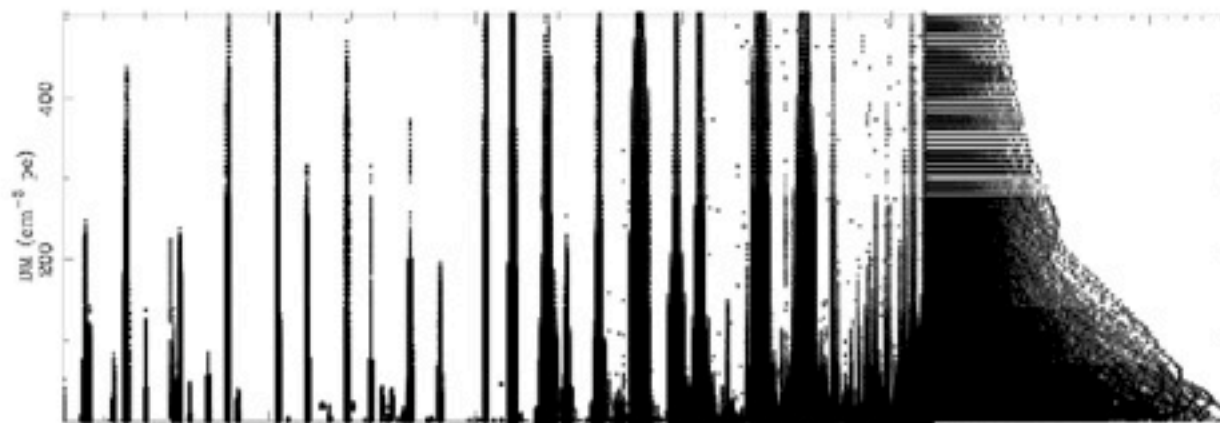


# RFI excision

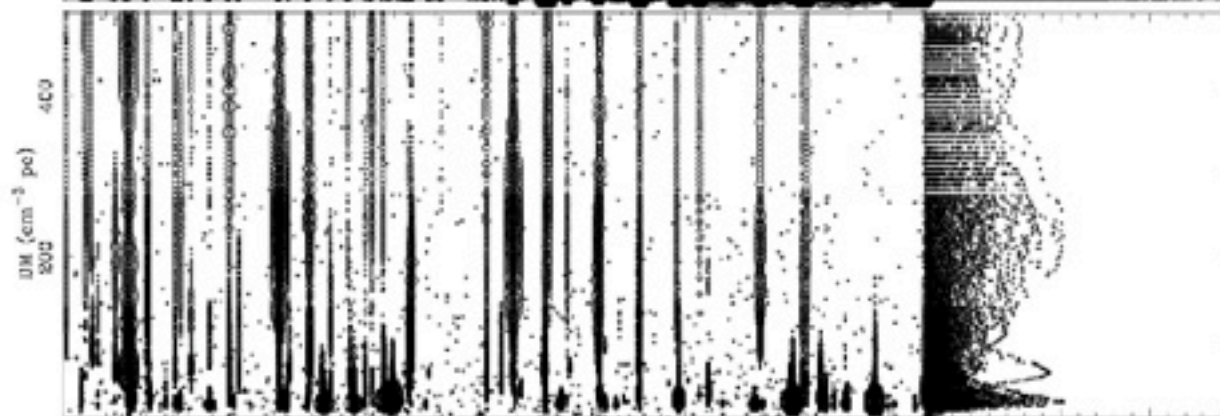
- Time- and/or frequency- based flagging (or zapping) – “thresholding”
- Persistent RFI can be estimated and subtracted
- A separate reference antenna can be used to characterise RFI to excise from data
- Adaptive nulling techniques
- Probability distribution analysis

– Fridman and Baan 2001, A&A 378, 327

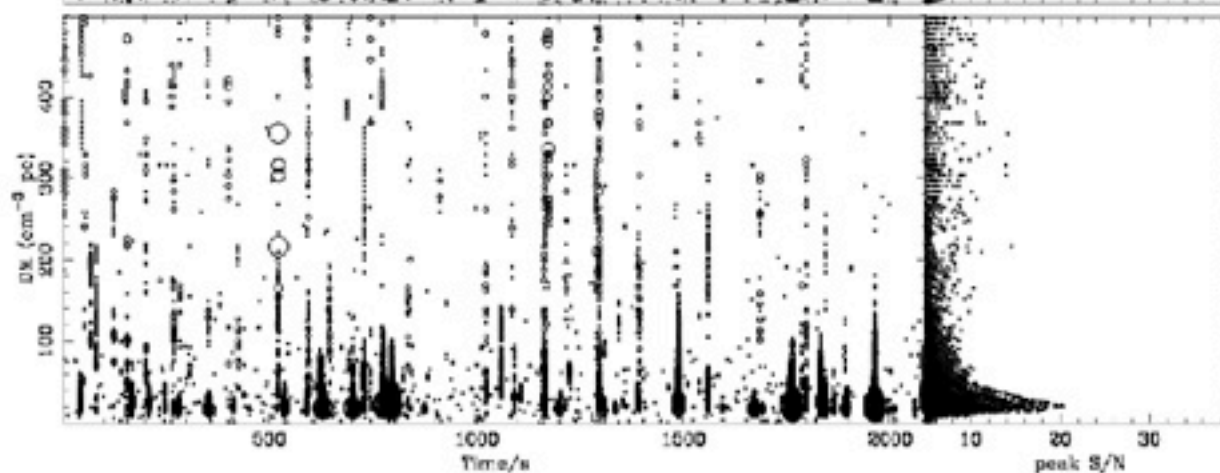
All data



Zero DM filter



+ Multi-beam filter



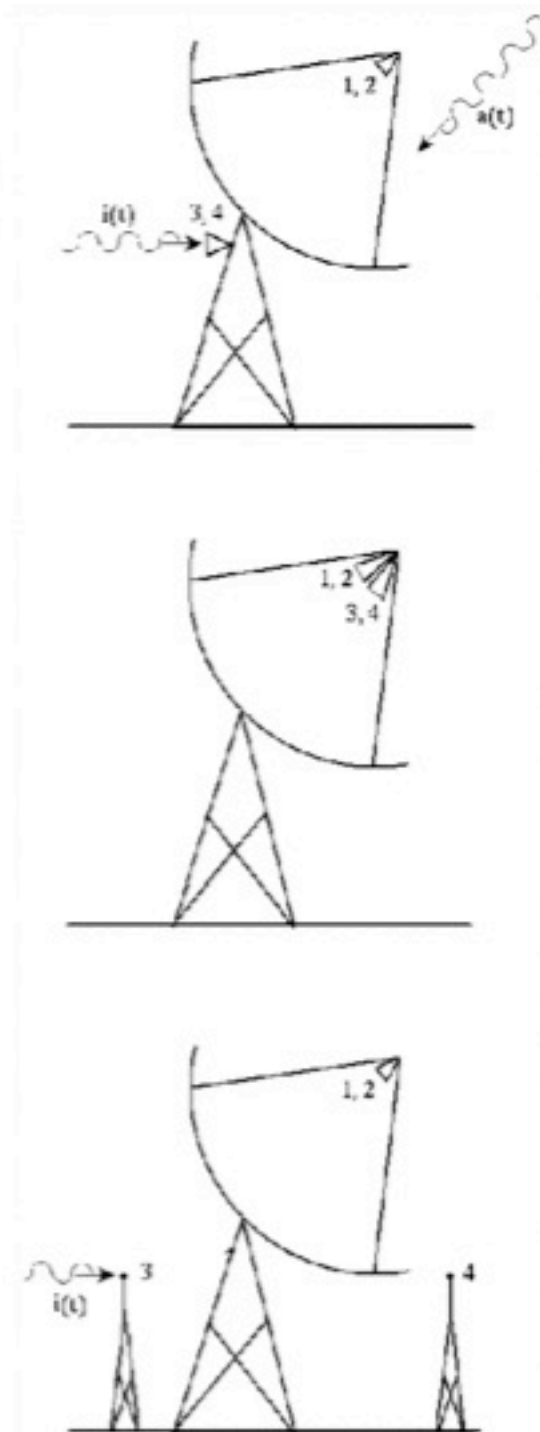
Searching for RRATs  
Keane et al  
arXiv:0909.1924

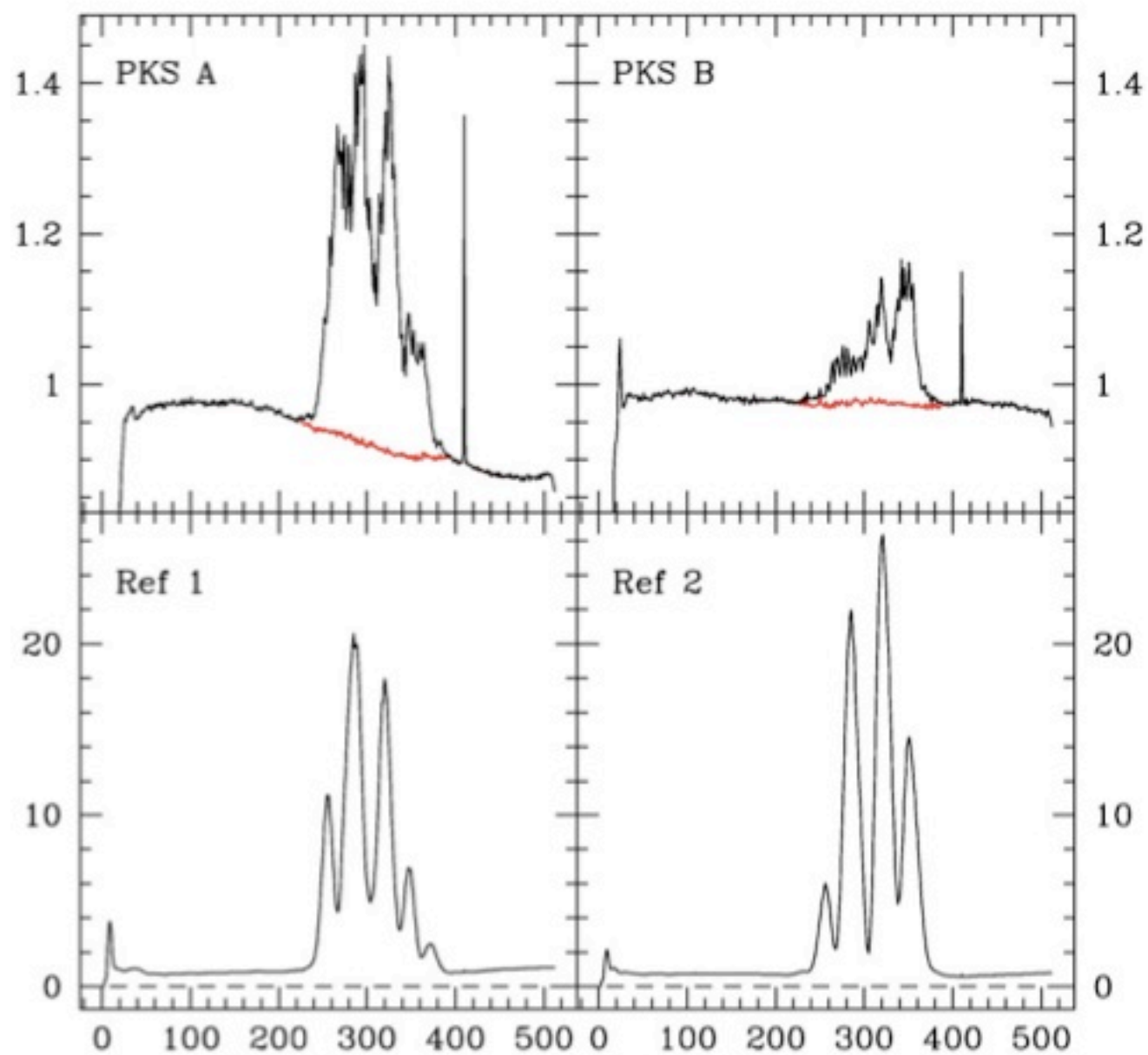
# Pieflag

- Editing of radio interferometer data can be laborious and time-consuming. Pieflag is a program which analyses radio interferometer data to filter out measurements which are likely to be affected by interference. Pieflag uses two algorithms to allow for data sets which are either dominated by receiver noise or by source structure. Together, the algorithms detect essentially all affected data whilst the amount of data which is not affected by interference but falsely marked as such is kept to a minimum.
- Pieflag a Python-based tool for automatically flagging ATCA data, Middelberg 2006, **PASA**, 23, 64
- <http://www.astro.rub.de/middelberg/pieflag/>

# Active cancellation

- Use additional receivers to characterise a source of persistent RFI, and remove this signature from the data
- Briggs, Bell & Kesteven 2000, ApJ 120, 3351





512 channels covering a 5 MHz band centred on 1499 MHz

# Case studies in tracking down RFI: Fault report 2426

- Little dependence on antenna angle, strong dependence on receiver rotation and translation
- Strongly suggests origin in focus cabin
- Traced to a synthesizer

# Fault Report 2981

- Continuous, strong source of RFI toward the west found in early 2008
- Appeared to be broadband
- Traced to Thuraya 3 satellite, launched into geostationary orbit in January 2008
- Frequency is outside receiver band but signal is so strong it causes compression in receiver package giving appearance of broadband RFI

# Fault Report 3053

- Strong impulsive RFI every few minutes
- Started in the morning, ended every afternoon
- Observed one Saturday night until 10pm
- Suggests origin in Visitors Centre
- Traced to faulty contacts in RCD connected to autoflush mechanism in mens toilet!



# A case from the GMRT

- (Thanks to Saikia for this story!)
- Giant Metrewave Radio Telescope
- 30 fully steerable parabolic dishes of 45m diameter each spread over distances of up to 25 km
- Designed to operate in six frequency bands centred around 50, 153, 233, 325, 610 and 1420 MHz

# Avoiding RFI

- Choose your frequency band, observing frequencies, time of day with care.
- Monitor your observations diligently.
- Use available tools to identify any RFI observed.
- Characterise RFI as best as you can.
- Edit data appropriately.

# Useful links

- [www.parkes.atnf.csiro.au/observing/rfi/](http://www.parkes.atnf.csiro.au/observing/rfi/)
- [www.narrabri.atnf.csiro.au/observing/rfi/](http://www.narrabri.atnf.csiro.au/observing/rfi/)
- [www.narrabri.atnf.csiro.au/operations/rfi.html](http://www.narrabri.atnf.csiro.au/operations/rfi.html)