Observing Strategies

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ASTRONOMY AND SPACE SCIENCE
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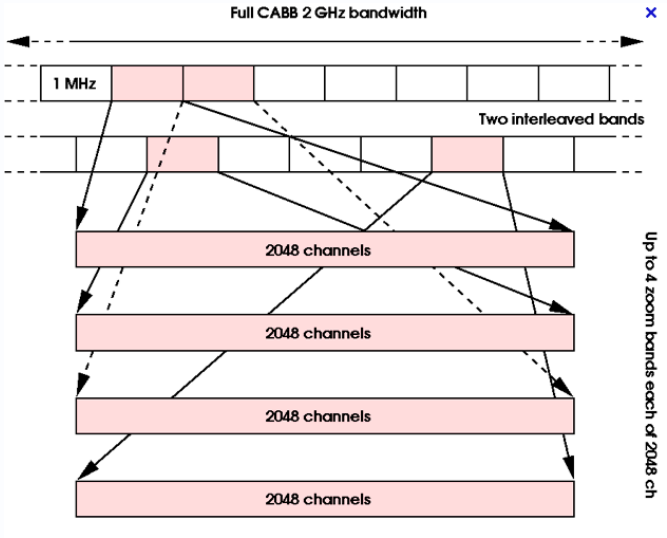
Outline

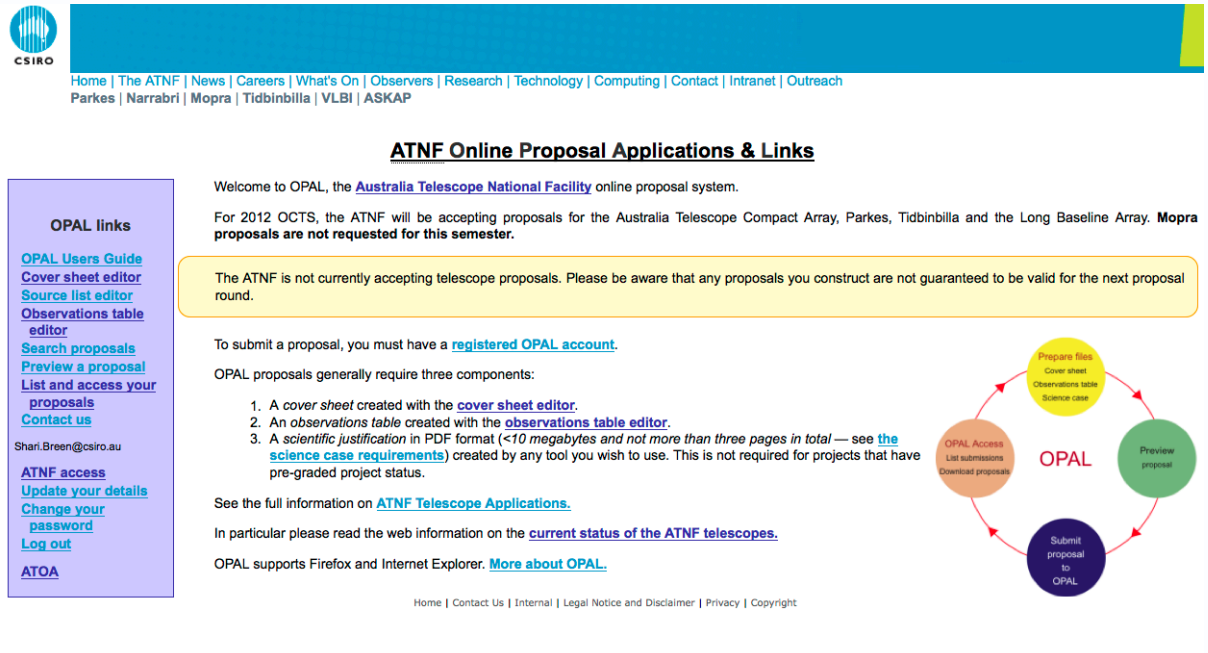
- Why is a good observing strategy important?
- Things to think about
  - What, when, for how long, frequency, array, overheads, CABB mode?
- Observing
  - The simple cm case
  - Slightly less simple cases
  - The mm case
  - Spectral lines



The importance of a good strategy

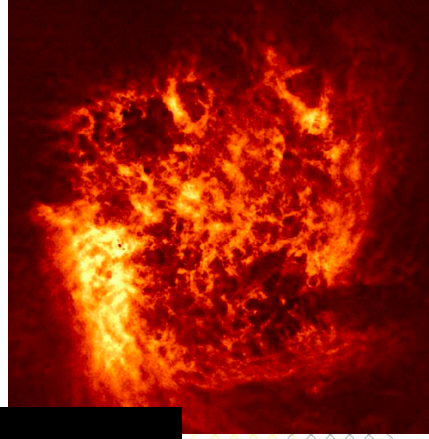
- Starts taking shape at the proposal stage
- Good telescopes are generally oversubscribed (ATCA usually by 2 – 3 times)

- Need to have a good plan to get good data that meets your science goals
- Make sure you are familiar with the current status of the instrument

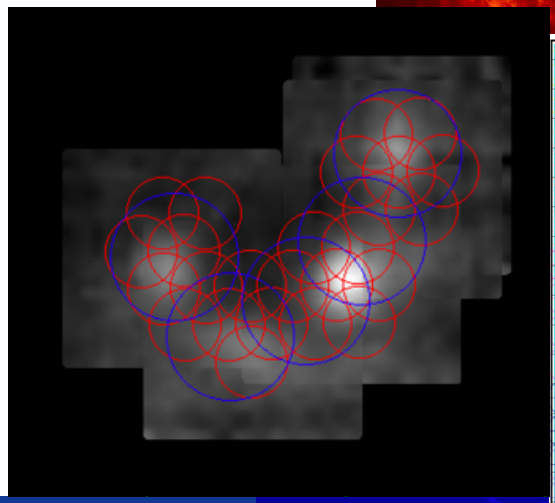


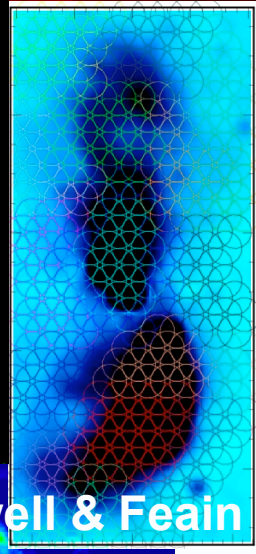
Things to thing about – 1) What?

- Strategy dependent on science/ object!
  - Complicated extended structure? → might need multiple array configs and single dish data
  - Point source? → a handful of short cuts over several hours might be enough
  - Know where your object is and just need a flux measurement or spectrum? → 1 short observation might be enough
  - Shadowing?
  - Confusion?
  - Location?
  - Mosaic? (primary beam λ/D)
  - Continuum and/or spectral line?

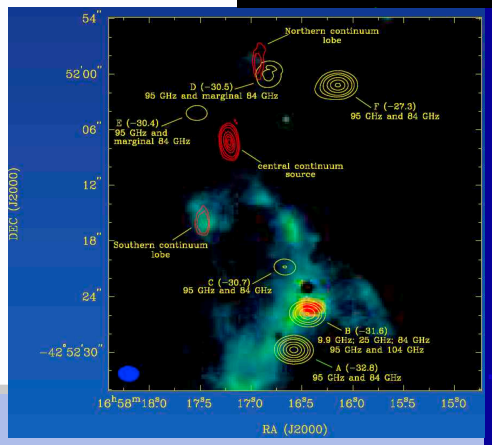


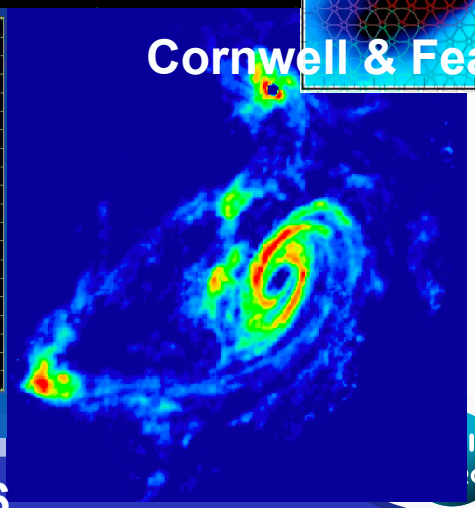
Kim et al.





Cornwell & Feain

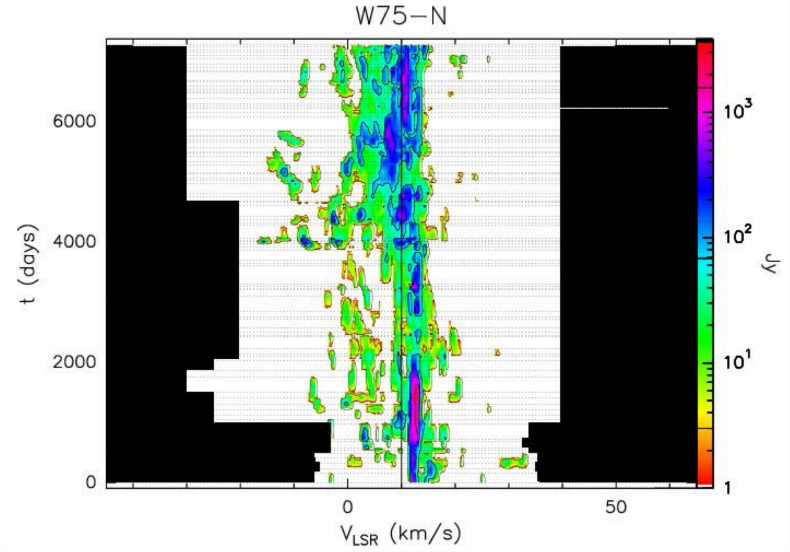




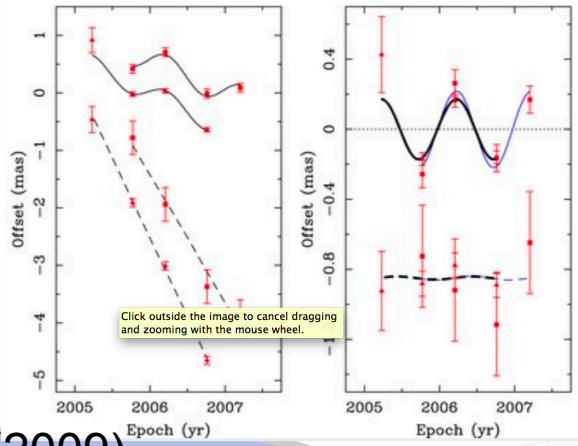
Voronkov et al. 2006

Things to thing about – 2) When?

- Variable source?
  - observe when it is expected to be bright
  - Or track the flux with observations spread over multiple epochs
- Coordination with other telescopes?
- Weather?
  - Atmosphere generally more stable at night → better mm observing
  - Generally less interference at night at the lower frequencies too (man made and solar)
  - Thunderstorms during afternoon in summer



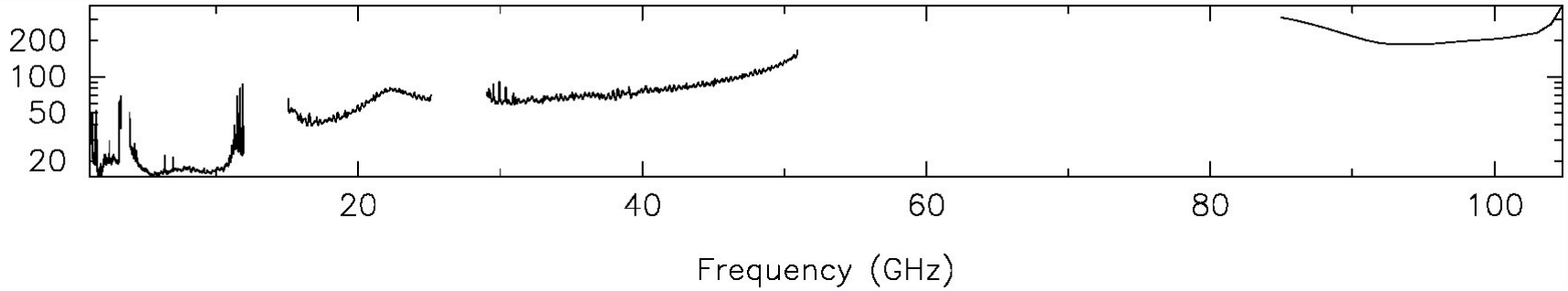
Felli et al. (2007)



Sanna et al. (2009)

Things to think about – 3) Frequency?

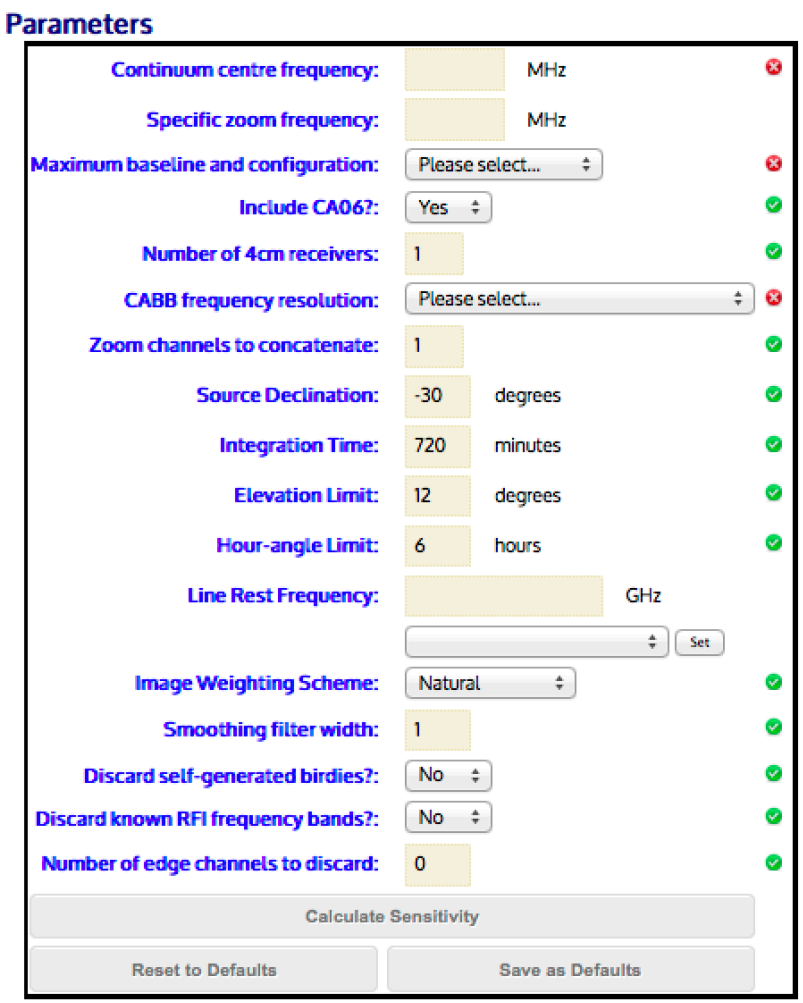
- Usually driven by science
  - Lines?
  - Remember to consider how the telescope performs at different frequencies
  - Spread the 2 IFs as far apart as possible, or continuous coverage?
  - Take the receiver limitations into consideration (e.g. the 13cm receiver works between 1.1 and 3.1 GHz)
  - ‘Standard’ continuum frequencies



Band	IF1 (MHz)	IF2 (MHz)
16cm	2100	2100
4cm	5500	9000
15mm	17000	19000
7mm (LSB)	33000	35000
7mm (USB)	43000	45000
3mm	93000	95000

Things to think about – 4) For how long?

- Mostly dictated by required sensitivity
  - Effective BW and spectral resolution
- UV coverage (e.g. bright spectral lines)
  - Short integrations across a range of hour angles increases overheads BUT may be the most efficient use of time to cover many sources



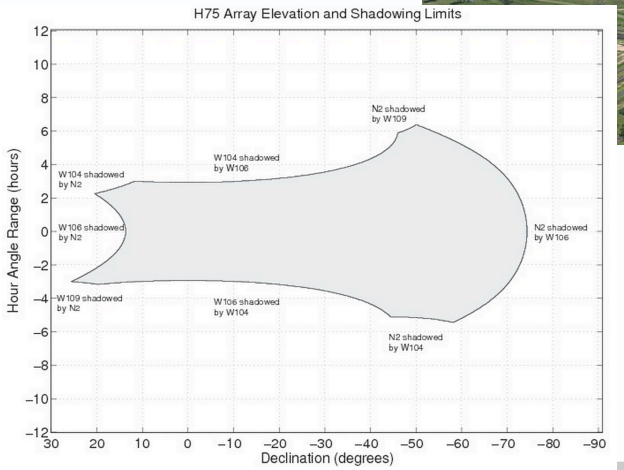
http://www.narrabri.atnf.csiro.au/myatca/sensitivity_calculator_advanced.html

Things to think about – 5) Array?

- Dictated by:
  - the resolution required
  - uv-coverage requirements (specific arrays work well together – 6A, 6C, 1.5B, 1.5D)
  - What's offered
  - Where your source is – shadowing?

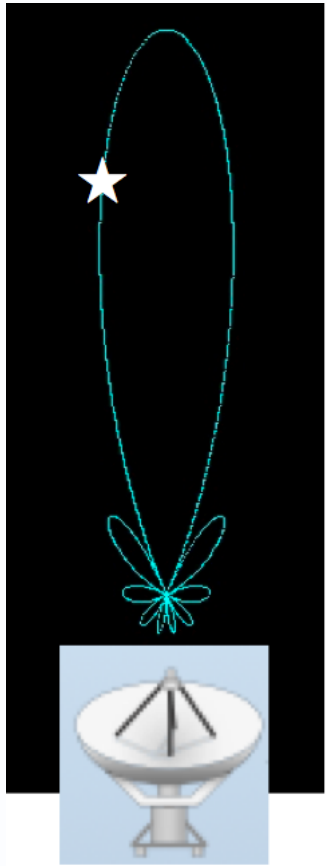
Semester	2010APRS	2010OCTS	2011APRS	2011OCTS	2012APRS
Array					
6A	•	•	•	•	•
6B			•		
6C	•			•	
6D		•			•
1.5A		•		•	
1.5B		•			•
1.5C			•		
1.5D	•			•	
750A		•			•
750B			•		
750C	•			•	
750D		•		•	
EW367		•		•	
EW352	•	•	•	•	•
H214	•	•	•		•
H168	•		•	•	•
H75	•		•		•

Table 1.3: Array configurations that will be offered in future semesters.



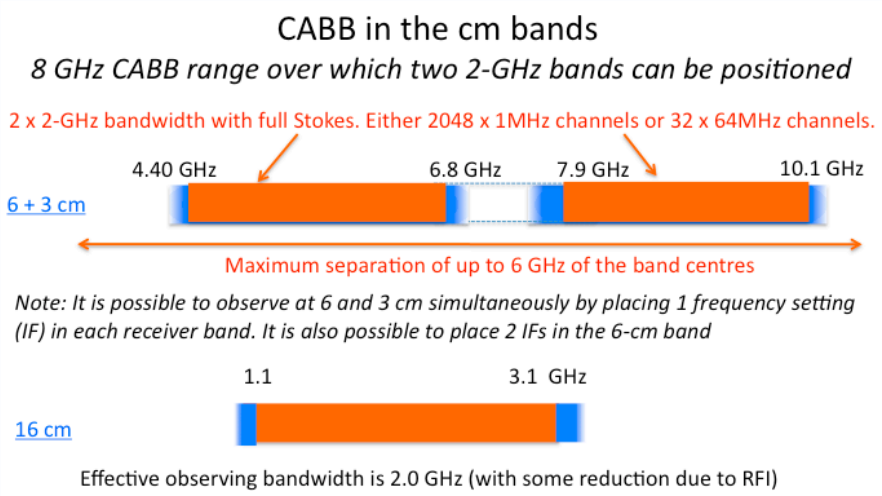
Things to think about – 6) Calibration and other overheads?

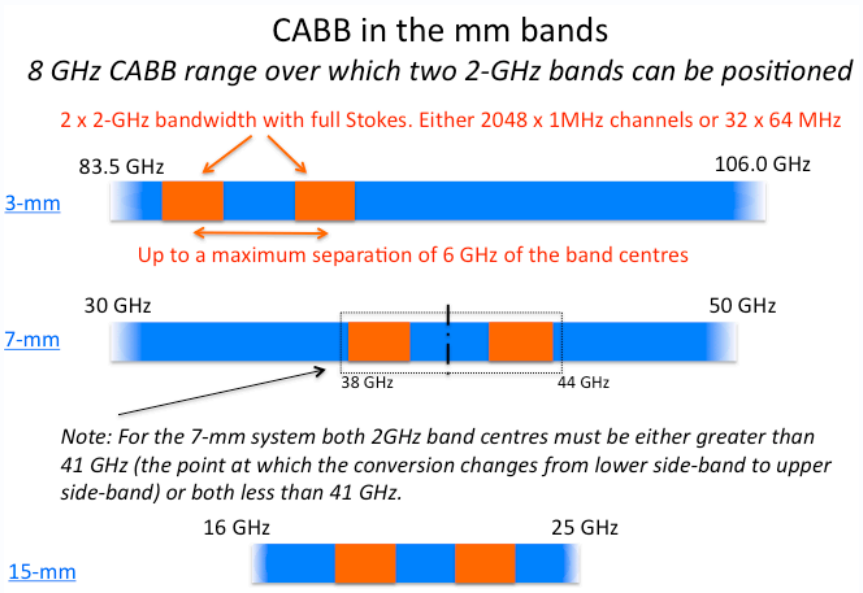
- Primary (flux) calibration
  - 1934-638 (or Uranus/Mars at mm)
- Bandpass calibration
  - 1934-638 strong enough at most cm wavelengths
  - 1253-055 or 1921-293 often used at higher frequencies
- Phase calibration (~2min every 40min)
  - Unresolved, strongish source within about 10 degrees of target
- Pointing calibration
  - Carried out every hour at all mm frequencies on a source within ~20 degrees of target
- Other overheads
  - Set up, slewing,…..



Things to think about – 7) CABB mode?

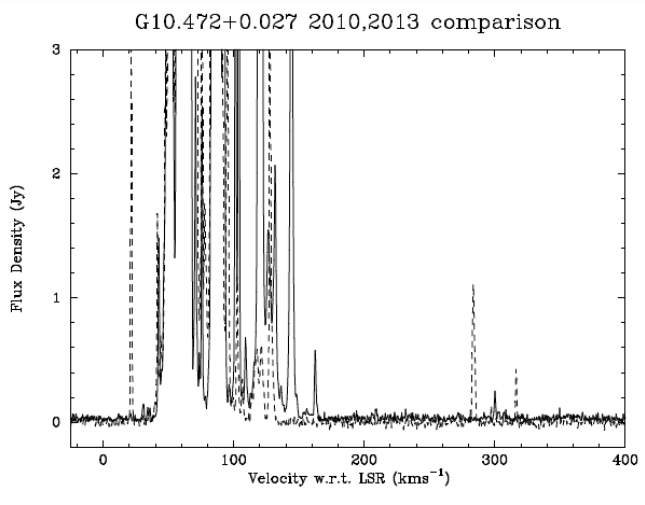
- Two x 2 GHz wide IFs (2048 x 1 MHz channels)
  - Where you can put them depends on the frequency

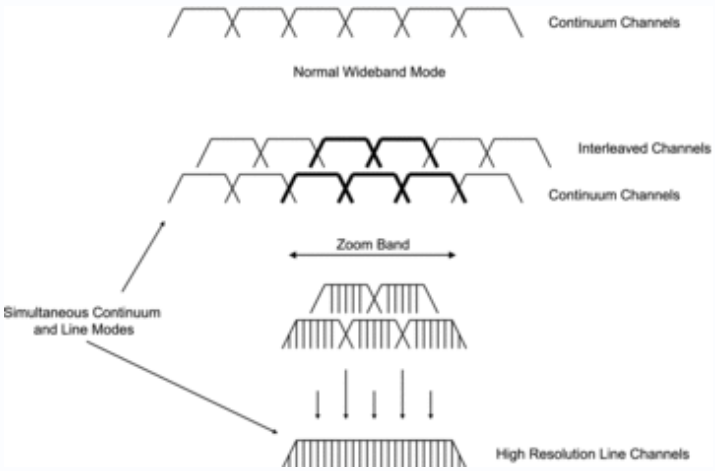


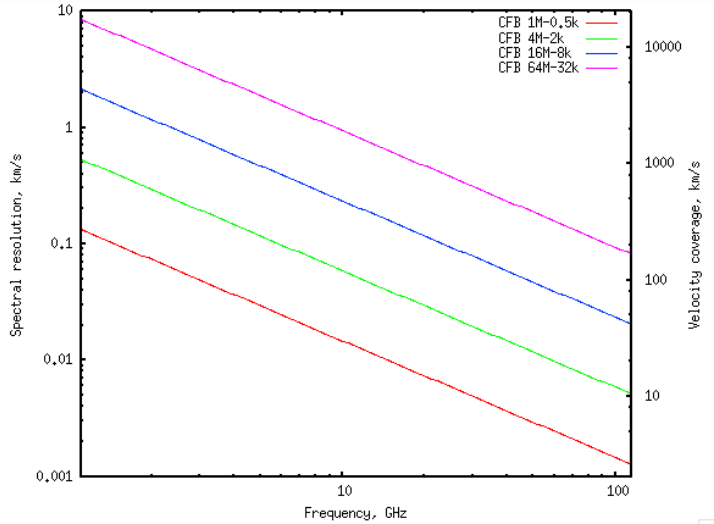


Things to think about – 7) CABB mode?

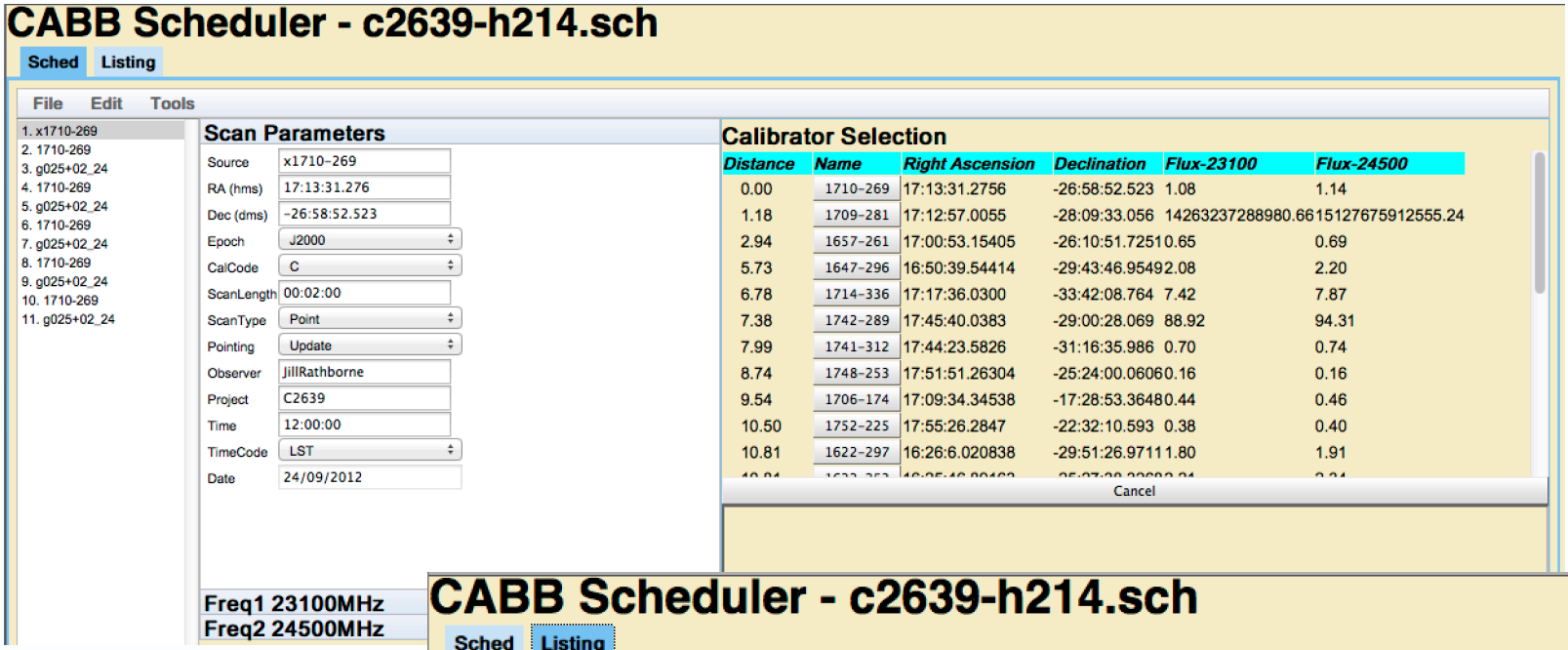
- Optional zoom windows (currently 32 x 1 MHz zooms or 64 MHz zooms each with 2048 channels)
  - Concatenate zoom windows for more velocity coverage
  - What mode depends on velocity res/coverage needed

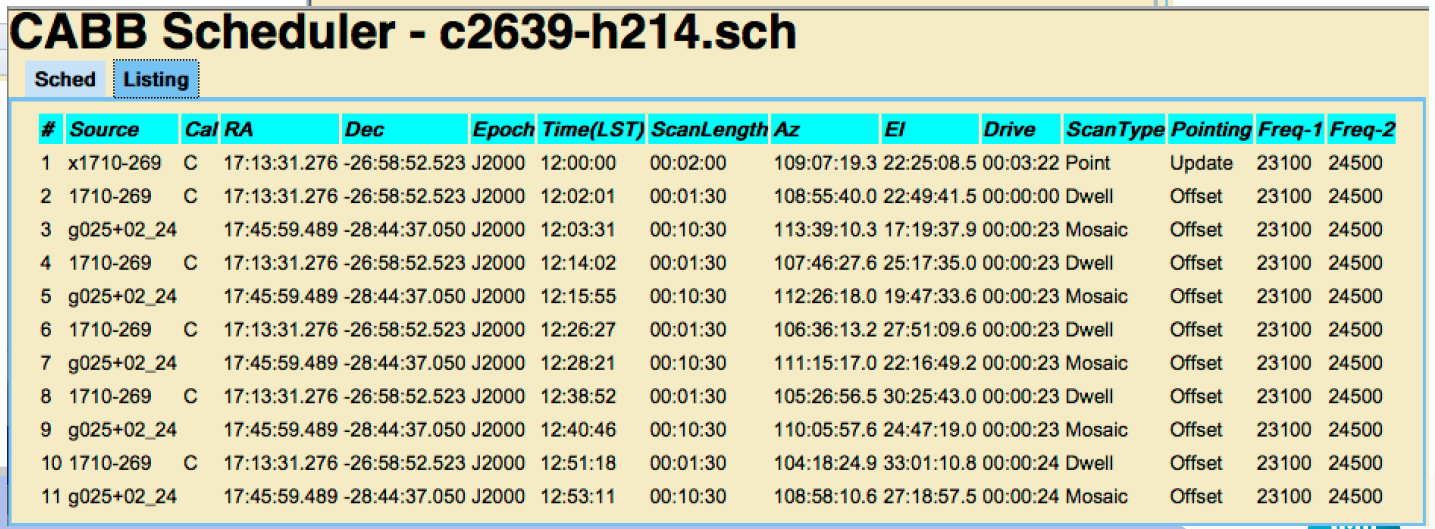






Schedule files https://www.narrabri.atnf.csiro.au/observing/sched/cabb/





Schedule files – adding line observations…

CABB Scheduler - c2986_7_12.sch

Sched | Listing | Frequency Zoom Range

File Edit Tools

1. 1253-055
2. 1253-055
3. 1253-055
4. 1253-055
5. 1817-254
6. 1817-254
7. bubble_22ghz
8. 1817-254
9. 1817-254
10. 7mm_bubble
11. 1817-254
12. 7mm_bubble
13. 1817-254
14. 7mm_bubble
15. 1817-254
16. 7mm_bubble
17. 1817-254
18. 1934-638
19. 1934-638
20. 1934-638
21. 0106+013
22. Uranus

New Scan | Search Cal | Delete | Pick Source

Scan Parameters

Freq1 43400MHz

Freq2 49000MHz

	Continuum (MHz)	Fixed	Chn.BW (MHz)	Vel.Res. (km/s)		Vel.Range (km/s)	#Channels
	49000	◉	6	392		12530	32
	Line		Channel		Width		2048
1 7 19	48136	○	6	0.19	1	398.6	Velo
2 8 20	48200		8	0.19	1	398.1	Velo
3 9 21	48360		13	0.19	1	396.7	Velo
4 10 22	48648		22	0.19	1	394.4	Velo
5 11 23	49000		33	0.19	1	391.6	Velo
6					1		Velo
7					1		Velo
8					1		Velo
9					1		Velo
10					1		Velo
11					1		Velo
12					1		Velo
13					1		Velo
14					1		Velo
15					1		Velo
16					1		Velo

Velocity Calculator

Source Velocity: 10 | LSR | Radio | Fix

Spectral Line: CS carbon monosulfide (48990.964 MHz)

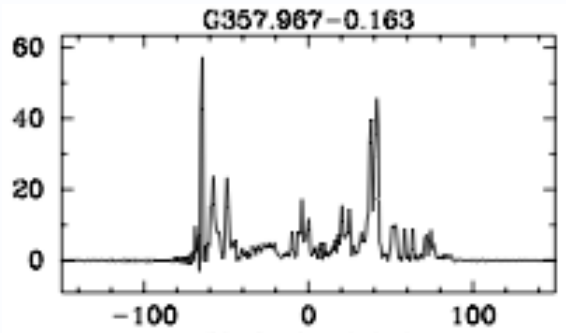
Rest Frequency: 48990

Observatory Velocity: 16.431

Sky Frequency: 48985.681

Zoom band Frequency: 49000

Cancel | Apply



CABB Scheduler - c2986_7_12.sch

Sched | Listing | Frequency Zoom Range

Enter a comma seperated list of rest freq in (MHz):

24934.382, 24928.707, 24933.468, 24959.0789, 25018.1225, 25124.8719, 22235.08, 44069, 48990

Check

Note: Please fill in CatVel for all the sources for the calculation to work correctly. And make sure you save the changes.

#	Source	24934.382	24928.707	24933.468	24959.0789	25018.1225	25124.8719	22235.08	44069	48990
1	bubble_22ghz	Zoom 6	Zoom 6	Zoom 6	Zoom 6	Zoom 8	Zoom 7	Zoom 1	X	X
2	7mm_bubble	X	X	X	X	X	X	X	Zoom 6	Zoom 11
3	7mm_bubble	X	X	X	X	X	X	X	Zoom 6	Zoom 11
4	7mm_bubble	X	X	X	X	X	X	X	Zoom 6	Zoom 11
5	7mm_bubble	X	X	X	X	X	X	X	Zoom 6	Zoom 11

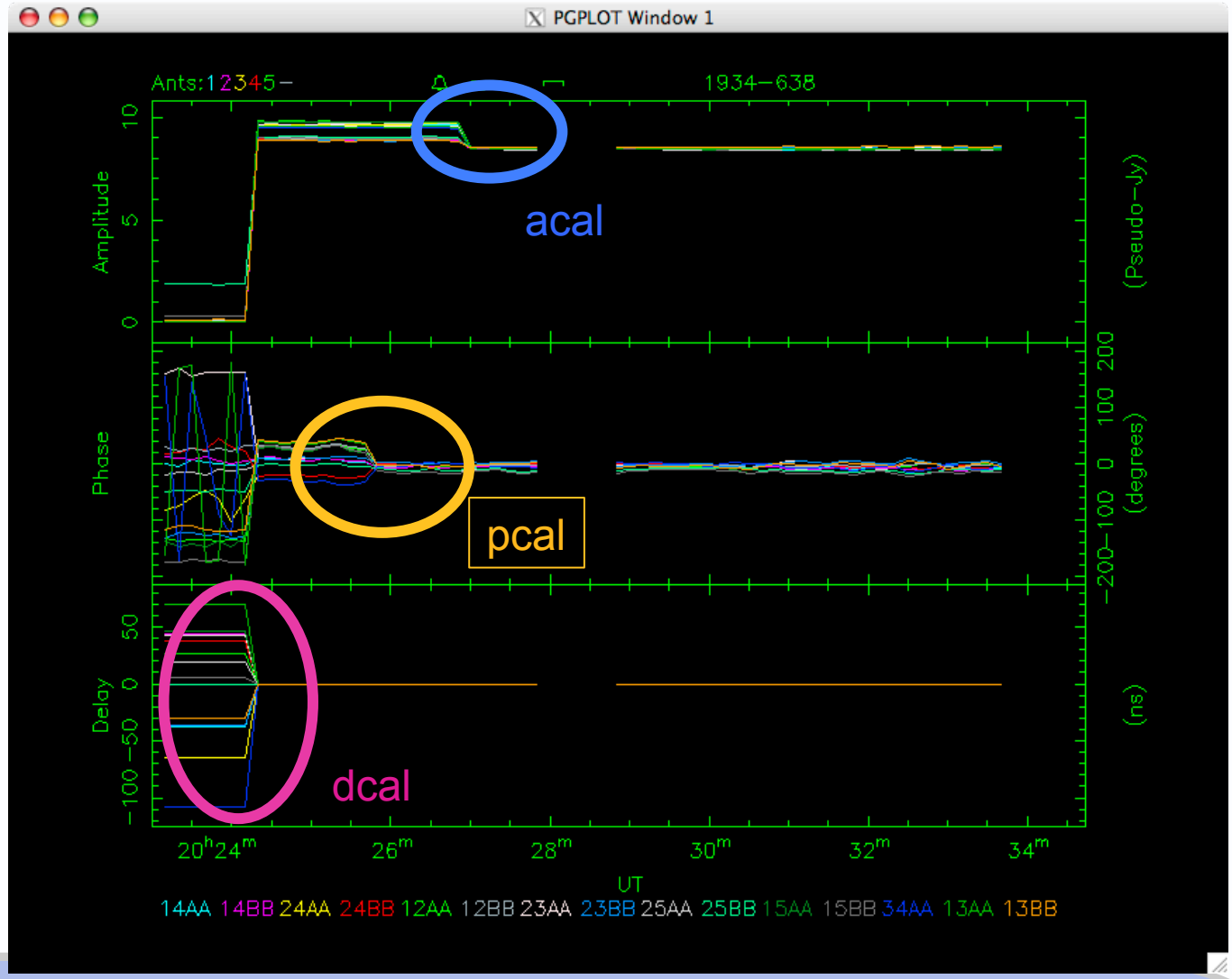
Need to calculate sky frequencies

- All done by the CABB scheduler

Observing – the simple cm case

- If you are prepared the actual observing is not hard
- A simple cm continuum observation of a single source may go something like
  - Observe 1934-638
    - Do initial array calibration (delays, phases, amplitudes; dcal, pcal, acal)
    - Close junk file
    - Track 1934-638 for primary and bandpass calibration (~10min)
  - Go to target schedule which contains
    - Phase calibrator (~2min)
    - Target (~20min)
    - Loop through target schedule until the end (start 1/99)

Calibrating the array



The less simple cases

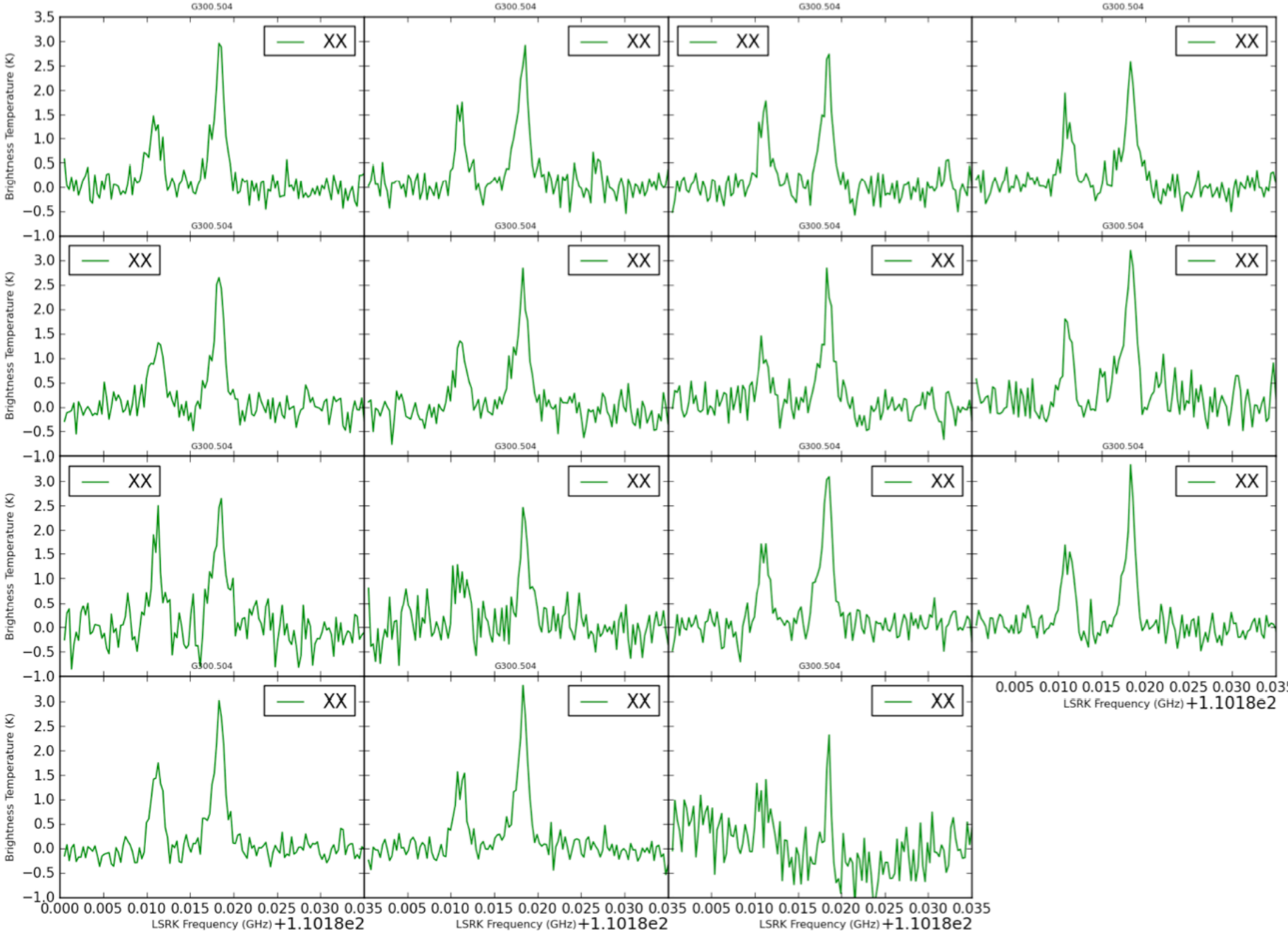
- Lower frequencies (~2.1 GHz)
  - Second IF is redundant
  - Lots of interference → need to choose channel range for calibration carefully (set “tvchan”)
  - More chance of confusion

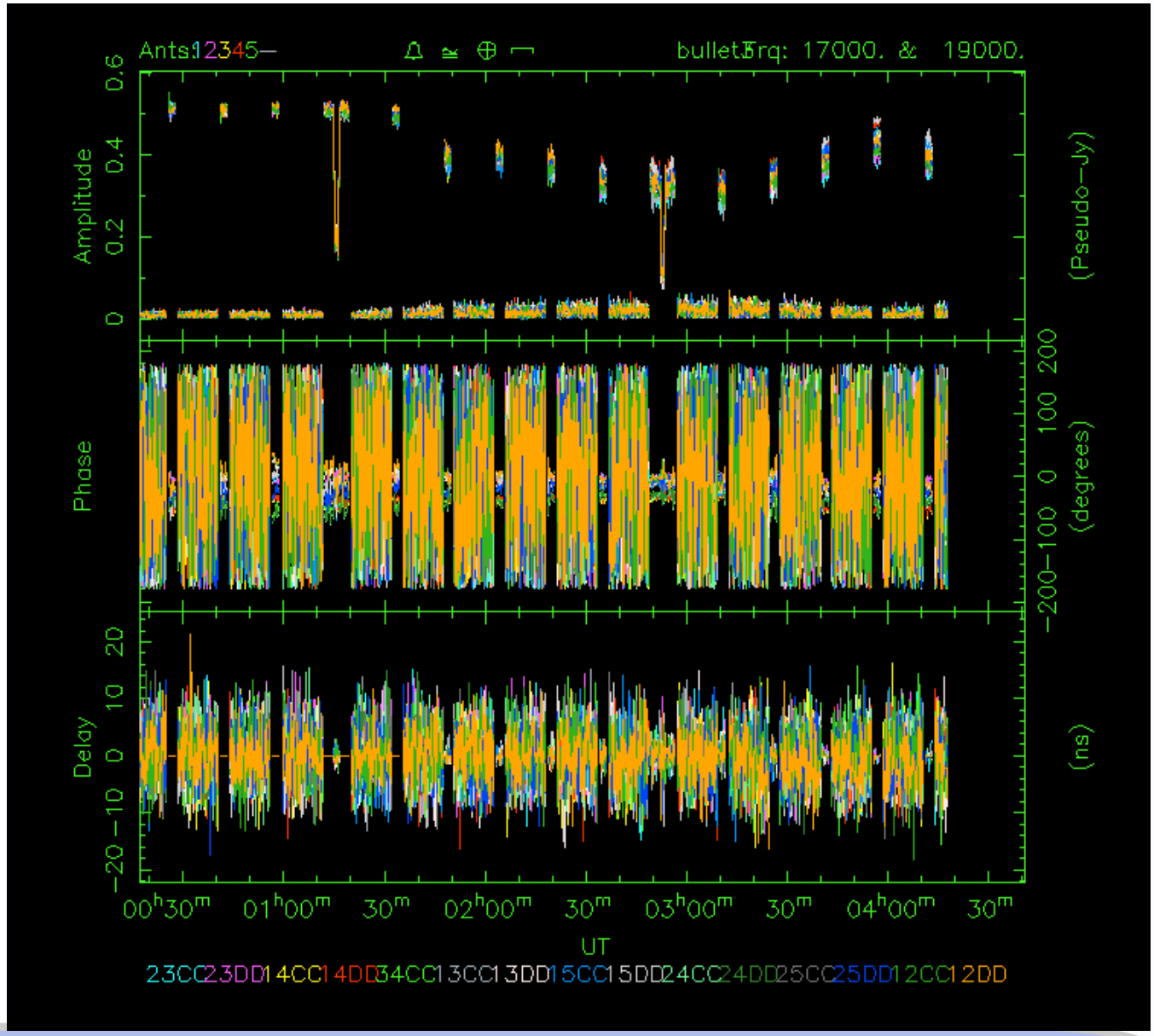
- Higher frequencies
  - 1934-638 gets too weak for setup and bandpass → use a stronger source (e.g. 0537-441, 1253-055, 1921-293)
  - Observe 1934-638 or a planet for primary calibration

mm observing – the least simple case

- Everything becomes more difficult at mm frequencies
  - Atmospheric opacity increases Tsys and attenuates signal
  - Not as many bright calibrator sources
  - Instrument stability is more difficult to maintain
  - Antenna accuracy is less
  - The FOV is smaller

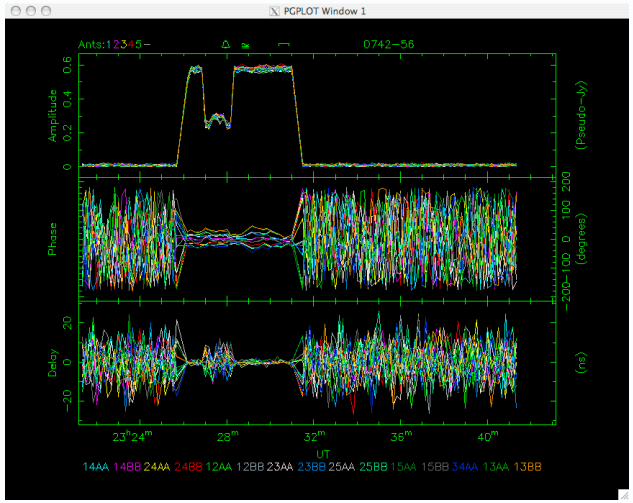
- To overcome some of these difficulties we usually only observe during the winter months (60-65 % chance of suitable 3mm weather) or during the night (esp at 12 or 7mm).


G300.504
XX
Brightness Temperature (K)
LSRK Frequency (GHz) +1.1018e2


Ants:12345—
bullet5rq: 17000. & 19000.
Amplitude
0
0.2
0.4
0.6
(Pseudo—Jy)
Phase
−200 −100 0 100 200
(degrees)
Delay
−20 −10 0 10 20
(ns)
00h30m
01h00m
30m
02h00m
30m
03h00m
30m
04h00m
30m
UT
23CC 23DD 14CC 14DD 34CC 13CC 13DD 15CC 15DD 24CC 24DD 25CC 25DD 12CC 12DD

Observing at mm frequencies

- Observe a strong caibrator (e.g. 0537-441, 1253-055 or 1921-295)
  - Calibrate delays (dcal)
  - Do a pointing (can choose specs)
  - Calibrate phase (pcal)
  - Calibrate amplitudes (acal or paddle at 3mm)



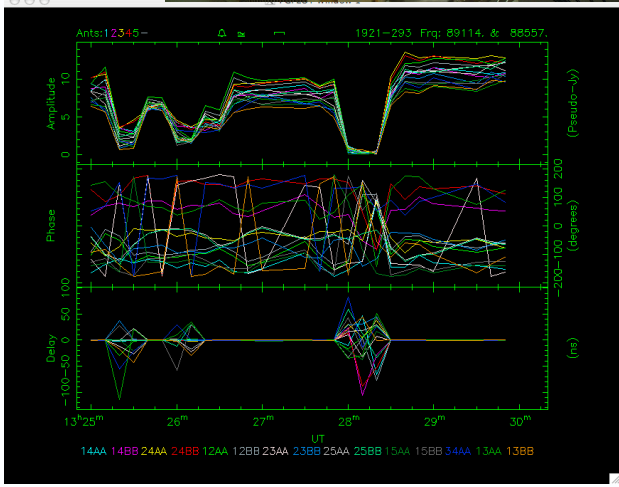
- Observe either 1934-638 (at 12 or 7mm) or a planet (at 3mm) for primary calibration
  - Pointing first (1934-638 or source nearby planet)
- Target observations
  - Include a pointing once an hour (ideally on a strong source within ~20 degrees)

Paddle scans

- Measure Tsys and correct for the atmosphere at 3mm
  - Place an ambient load in front of receiver horn for 30 sec
  - Gives Tsys corrected for the current atmospheric conditions

$$T_{sys}^{eff} = (300\ K)\ \frac{P_{sky}}{P_{paddle} - P_{sky}}$$

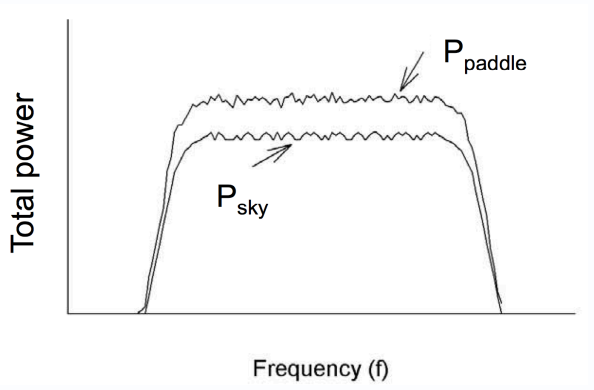
- Every 15-20min
- Before primary and bandpass calibrators



CABB Scheduler - c2639-sio.sch

Sched | Listing

#	Source	Cal	RA	Dec	Epoch	Time(LST)	ScanLength	Az	El	Drive	ScanType	Pointing	Freq-1	Freq-2
1	x1730-130	C	17:33:02.706	-13:04:49.548	J2000	12:00:00	00:01:30	98:11:44.5	12:08:12.0	00:03:54	Point	Update	85908	87400
2	1730-130	C	17:33:02.706	-13:04:49.548	J2000	12:01:30	00:01:30	98:00:57.2	12:27:29.0	00:00:00	Paddle	Offset	85908	87400
3	1730-130	C	17:33:02.706	-13:04:49.548	J2000	12:03:00	00:01:30	97:50:10.0	12:46:46.4	00:00:00	Dwell	Offset	85908	87400
4	g025+02_86		17:46:02.704	-28:44:09.110	J2000	12:04:31	00:12:00	113:33:09.5	17:30:32.4	00:00:34	Mosaic	Offset	85908	87400
5	1730-130	C	17:33:02.706	-13:04:49.548	J2000	12:16:33	00:01:30	96:13:05.9	15:40:44.6	00:00:34	Paddle	Offset	85908	87400
6	1730-130	C	17:33:02.706	-13:04:49.548	J2000	12:18:03	00:01:30	96:02:18.0	16:00:06.6	00:00:00	Dwell	Offset	85908	87400
7	g025+02_86		17:46:02.704	-28:44:09.110	J2000	12:19:33	00:12:00	112:05:16.7	20:30:03.9	00:00:34	Mosaic	Offset	85908	87400
8	1730-130	C	17:33:02.706	-13:04:49.548	J2000	12:31:35	00:01:30	94:24:48.8	18:54:40.1	00:00:35	Paddle	Offset	85908	87400
9	1730-130	C	17:33:02.706	-13:04:49.548	J2000	12:33:05	00:01:30	94:13:56.1	19:14:05.4	00:00:00	Dwell	Offset	85908	87400
10	g025+02_86		17:46:02.704	-28:44:09.110	J2000	12:34:36	00:12:00	110:40:05.0	23:31:26.1	00:00:35	Mosaic	Offset	85908	87400
11	1730-130	C	17:33:02.706	-13:04:49.548	J2000	12:46:38	00:01:30	92:35:22.0	22:09:04.0	00:00:35	Paddle	Offset	85908	87400
12	1730-130	C	17:33:02.706	-13:04:49.548	J2000	12:48:08	00:01:30	92:24:19.6	22:28:31.5	00:00:00	Dwell	Offset	85908	87400
13	g025+02_86		17:46:02.704	-28:44:09.110	J2000	12:49:38	00:12:00	109:17:17.2	26:34:29.0	00:00:35	Mosaic	Offset	85908	87400



How do we measure tsys and correct for the atmosphere at 3mm?

If you forget to calibrate the phases during your setup (pcal) are your observations ruined?

What are the two main ways the atmosphere makes it difficult to detect signals at mm wavelengths?

What are the two main ways the atmosphere makes it difficult to detect signals at mm wavelengths?

What are the different CABB modes?

What is shadowing and when is it a problem?

At what frequency are pointing observations required and why?

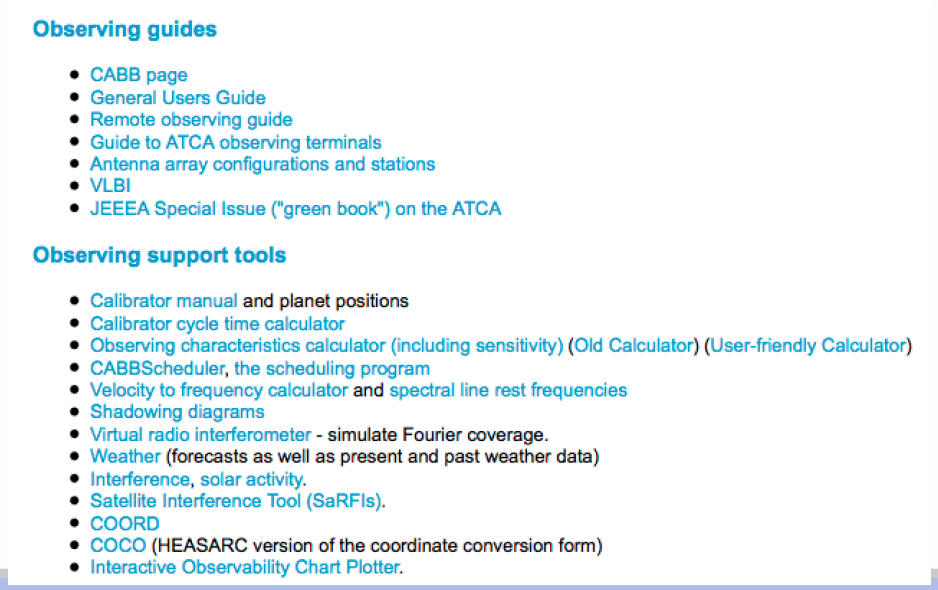
How far from your target source can your phase calibrator be?

In what band does interference cause the biggest problem?

What do you think the most important things to consider when formulating your observing strategy are?

Summary and further information

- Have a plan and make sure it is a good one!
- Different science goals require different strategies so think carefully about what is required
- See ATCA webpage for further information: http://www.narrabri.atnf.csiro.au/observing/



Observing guides

- CABB page
- General Users Guide
- Remote observing guide
- Guide to ATCA observing terminals
- Antenna array configurations and stations
- VLBI
- JEEEA Special Issue ("green book") on the ATCA

Observing support tools

- Calibrator manual and planet positions
- Calibrator cycle time calculator
- Observing characteristics calculator (including sensitivity) (Old Calculator) (User-friendly Calculator)
- CABBScheduler, the scheduling program
- Velocity to frequency calculator and spectral line rest frequencies
- Shadowing diagrams
- Virtual radio interferometer - simulate Fourier coverage.
- Weather (forecasts as well as present and past weather data)
- Interference, solar activity.
- Satellite Interference Tool (SaRFIs).
- COORD
- COCO (HEASARC version of the coordinate conversion form)
- Interactive Observability Chart Plotter.

Thank you

Astronomy and Space Science
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