Observing Strategies at cm wavelengths

Making good decisions

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Radio Continuum Observations

- Frequencies
- Angular resolution (λ/B)
- Array configurations
- Calibration strategies
- Integration times
- Interference and confusion

ATCA - cm continuum observations

λ (cm):	3	6	13	20
ν(GHz):	8.0 ▸ 9.2	4.4 ▸ 6.7	2.2 ▸ 2.2	1.25 ▸ 1.78
Prim.beam (arcmin):	5	10	22	33
Synth. Beam (arcsec) :	1	2	4	6

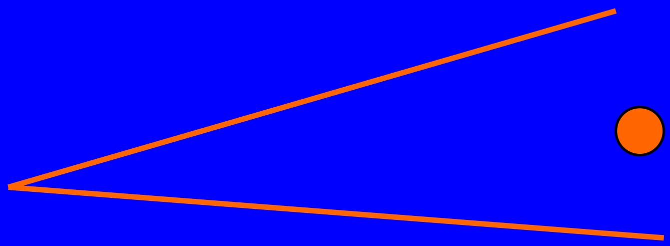
- Bandwidth = 128 MHz split into 32 spectral channels
- Switching between bands is straightforward
- Allows for simultaneous observations at 3+6 cm and 13+20 cm

Frequency Considerations

- image resolution
- do you want spectral indices?
- is emission thermal or non-thermal?
- system performance
- confusion and interference
- phase stability

Choice of ATCA band(s) is usually SCIENCE DRIVEN

Angular resolution and array choice



For point source:

Flux = S (mJy)

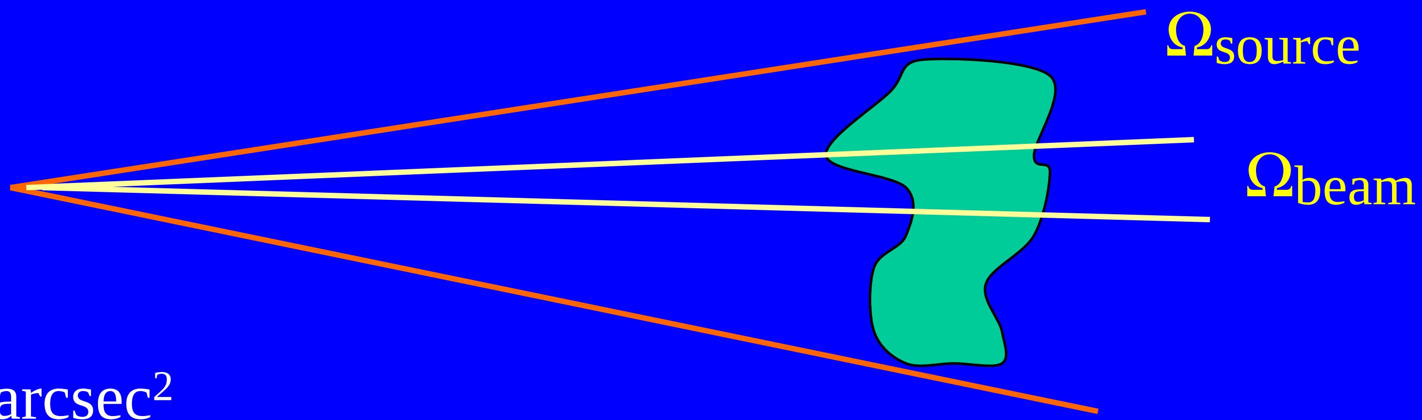
Brightness = S (mJy/beam area)
(same for any beam area)

rms noise = ΔI (mJy/beam area)

signal/noise = S/ ΔI

Sensitivity to a point source is the same for all baselines

Sensitivity to an extended source



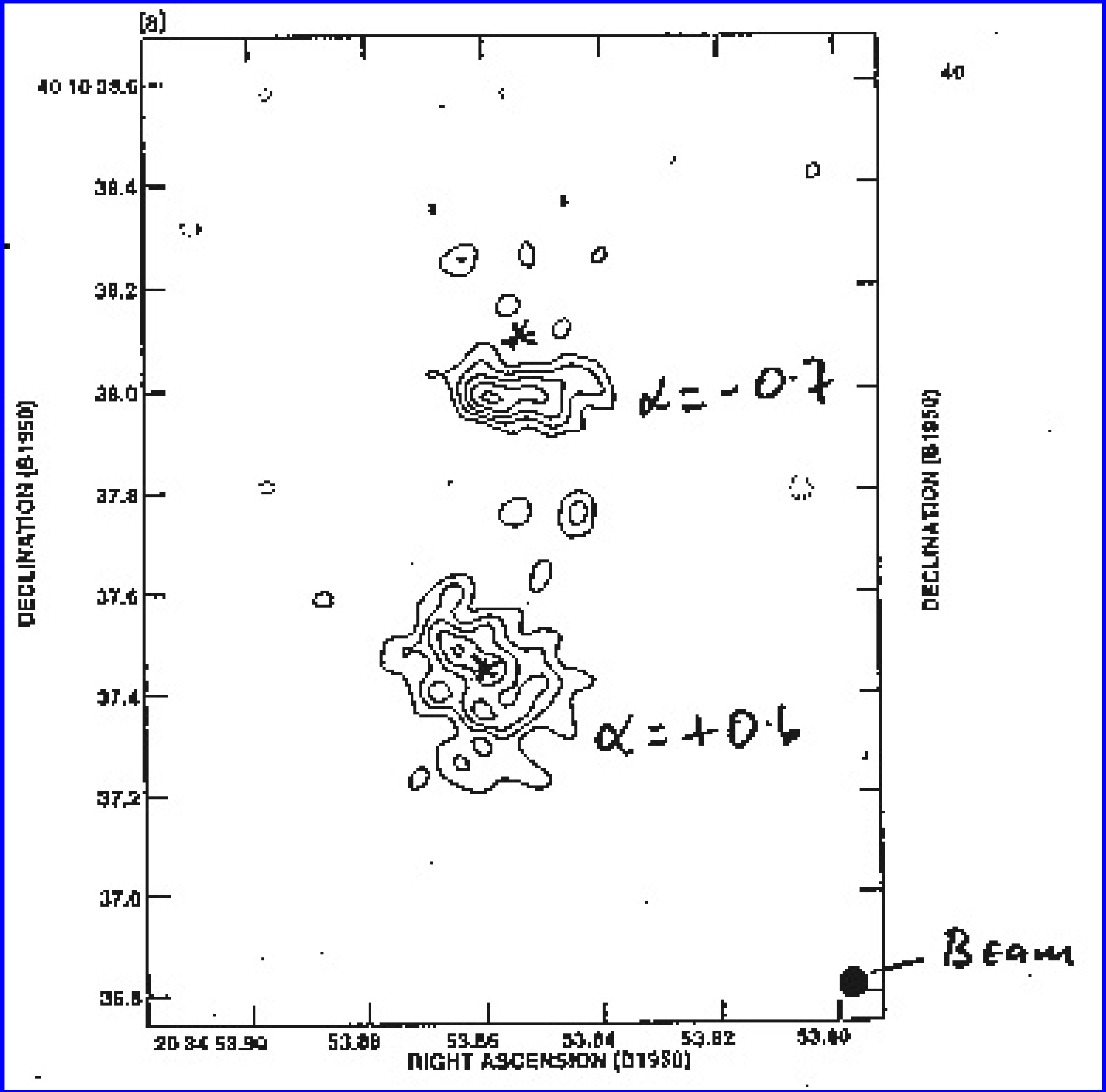
Flux = I mJy/arcsec^2

Beam area = Ω_B (For a Gaussian beam, $\Omega_B = 1.113\Theta_x \Theta_y$)

Signal/noise = $I\,\Omega_B / \Delta I$ ($\propto$ beam area)

If beam area < source size then the sensitivity to extended emission is reduced.

Note the trade off between angular resolution and brightness sensitivity.



WR 147

MERLIN: - total flux density = 20 mJy

VLA: - total flux density = 36 mJy

Choosing best configurations

- Smallest angular structure $\longrightarrow$ longest baseline
- Largest angular structure $\longrightarrow$ shortest baseline
- Determine full size of full region for image
- Select best matched array configurations

Compact Array Configurations

Large number available - baselines from 30 m to 6 km

- 39 ‘stations’ on the 3-km east-west track (Bmax = 3 km)
- 1 station at 6-km
- 5 stations on new north-south arm (Bmax = 214 m).

For complex sources – it is often advisable to use 2 or more configurations.

For available configurations see the

“Guide to Observations with the Compact Array”

Compact Array configurations 2002 - 2005

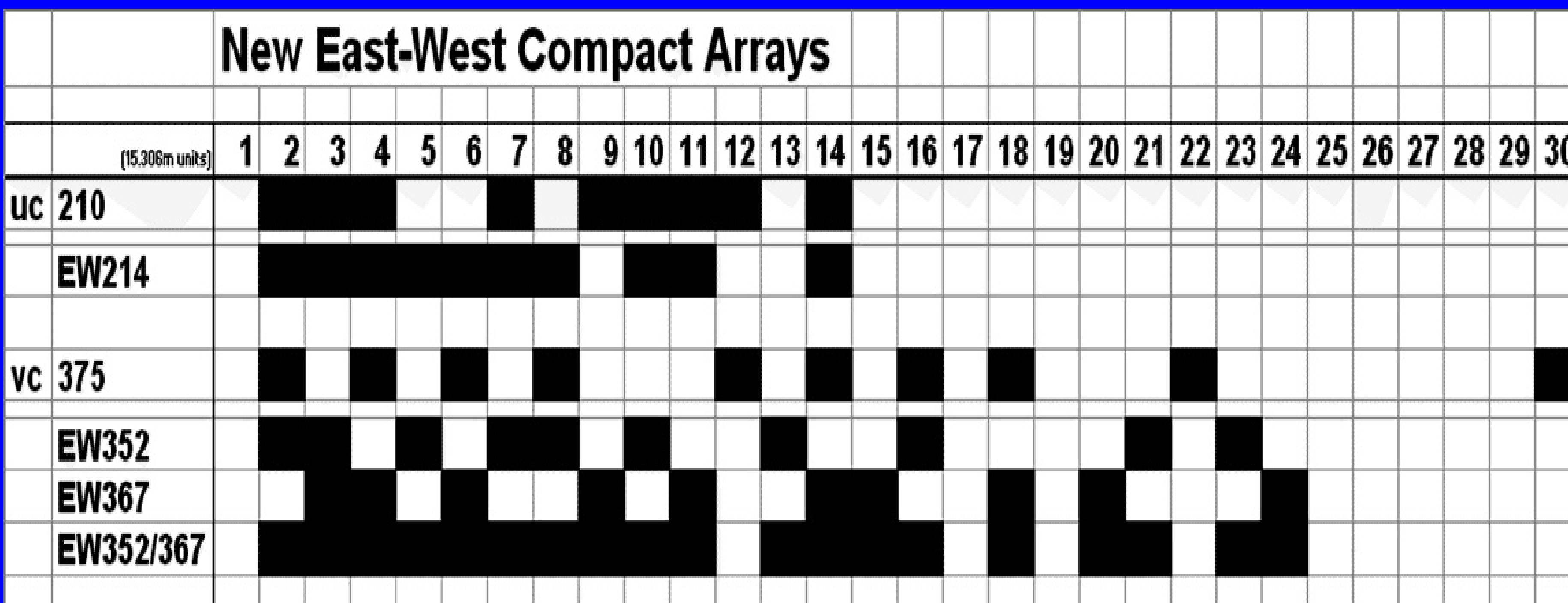
Array	Years and Terms									
	2002	2003			2004			2005		
	3	1	2	3	1	2	3	1	2	3
6.0A	●	●		●		●		●		●
6.0B		●			●				●	
6.0C	●						●			
6.0D			◉					●		
1.5A	●				●				●	
1.5B		●				●				●
1.5C			◉				●			
1.5D				●				●		
750A	●				●				●	
750B				●				●		
750C			◉				●			
750D		●				●				●
EW367	●		◉							
EW352		●		●						
EW214			◉							
H214				●						
H168	●									
H75										
NS214										
122B										

There are several 'new' array configurations:

- EW352/367
- EW214
- H75 (hybrid)
- H168 (hybrid)

Complementary configurations – an example

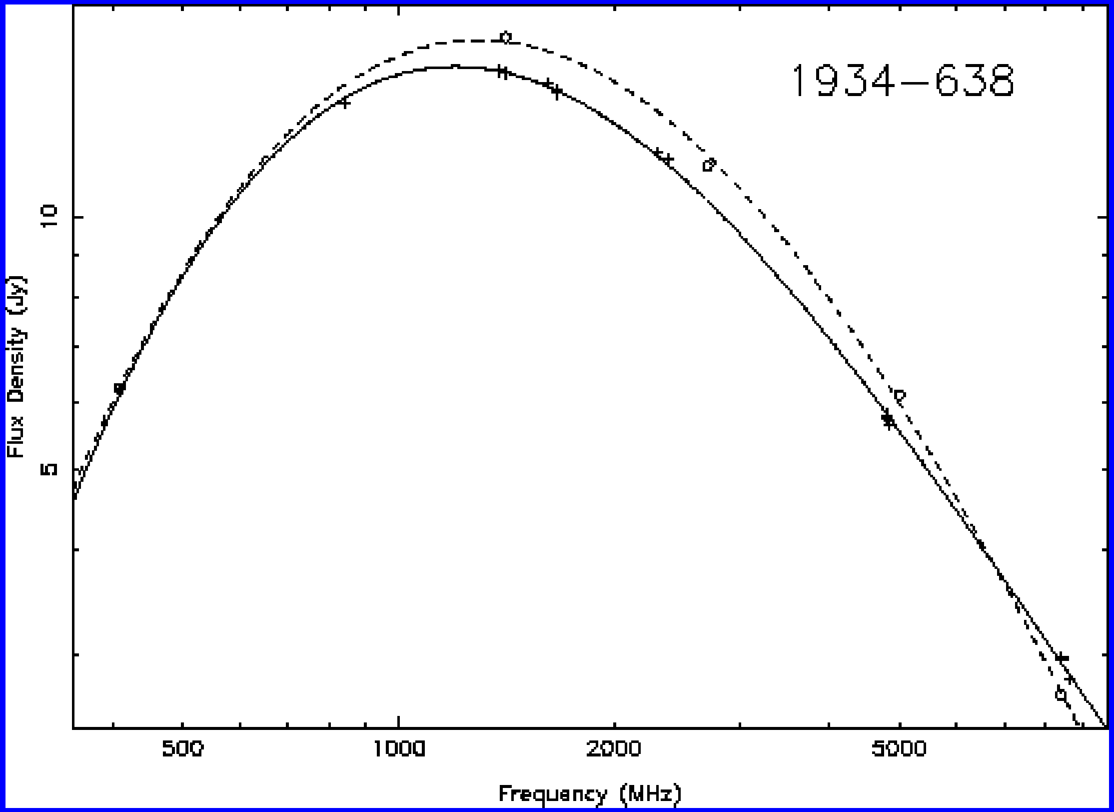
EW 352 + EW 367 provides almost uniform coverage for baselines from 30 m to 370 m.



Calibration

I: Primary amplitude calibration

Observations of a strong, non-variable and compact source with a known flux density are used to determine the absolute flux scale.

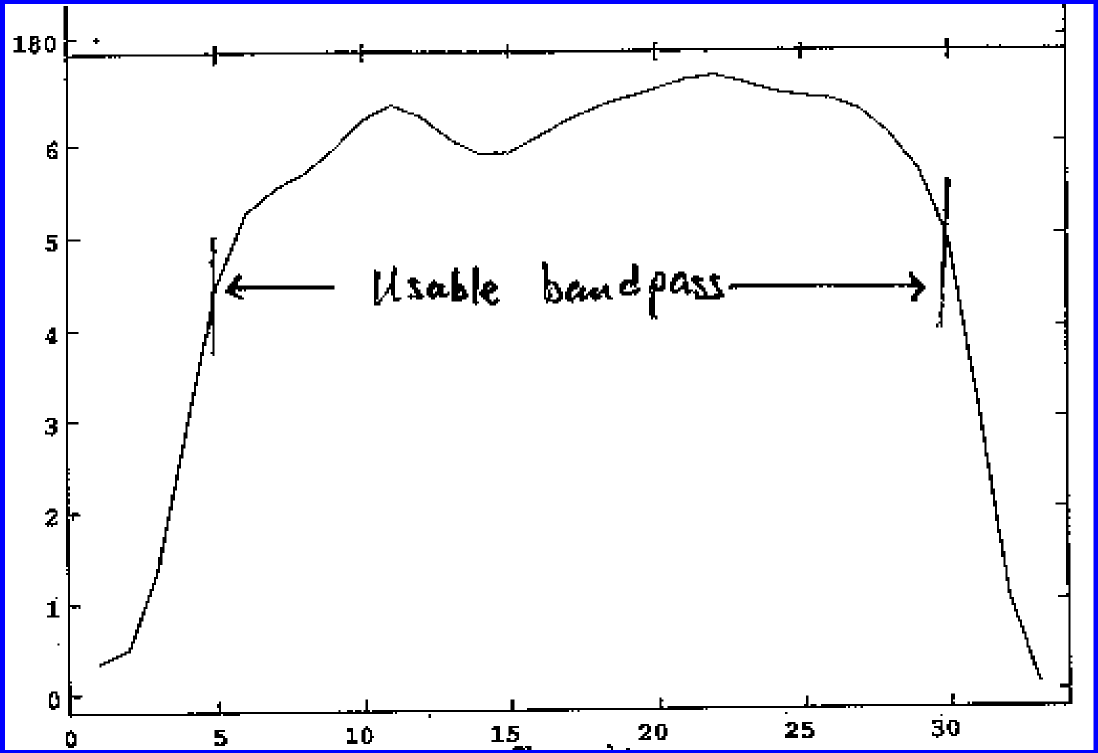


1934-638 is used as the primary calibrator for all ATCA cm observations

II Bandpass calibration

Observations of 1934-638 or another strong compact source are used to correct for instrumental variations across the bandpass. A single bandpass calibration observation of about 10 minutes is usually sufficient.

Amplitude (Jy)



Channel number

III Secondary Calibration

Secondary calibration sources are observed to correct for time-dependent visibility variations caused by instrumental effects and the atmosphere.

Observe secondary calibration sources which are:

- strong (> 1 Jy)
- close to source (< 10-15 degrees)
- unresolved on all baselines
- have accurate positions

At 20 cm Secondary calibration sources are typically observed for a few minutes every 45 minutes.

At 3 cm – need to monitor phase stability and do more frequent Calibration observations.

Finding calibrator sources

To list calibration sources at Narrabri:

On Leon (Vax) > Print AT$CAT:AT.CAT

> Print AT$CAT:VLA.CAT

Or use the on-line search facility

http://www.narrabri.atnf.csiro.au/calibrators

Integration times

Thermal noise at image centre :

$$\Delta I_{th} \; \alpha \; Tsys . F / (n_{bas} . BW . T. n_{pol})^{0.5}$$

Tsys (cm) ~ 340 – 450 Jy

F ~ 1.0 for natural weighting, ~ 1.5 for uniform weighting

Examples: BW = 128 MHz. Npol = 2

T = 12 hours, ΔI_{th} ~ 0.025 mJy

T = 10 mins, ΔI_{th} ~ 0.21 mJy

Sensitivity calculator -www.atnf.csiro.au/observers/docs/at_sens

In practise, to reach the thermal noise, need to have a well-sampled u-v plane.

Short-cut detection experiments

- split the total time into a large number of short cuts
- distribute cuts over the HA range of source

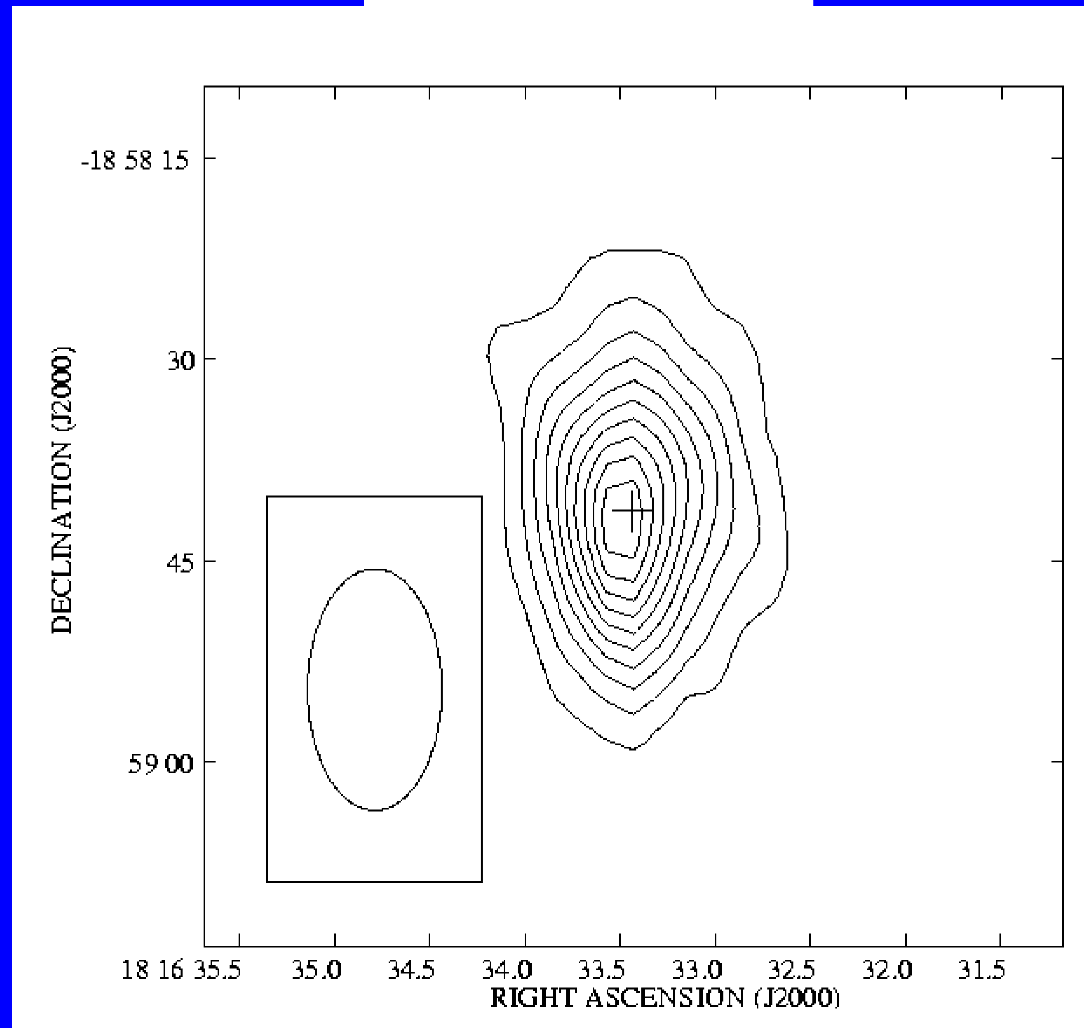
This should

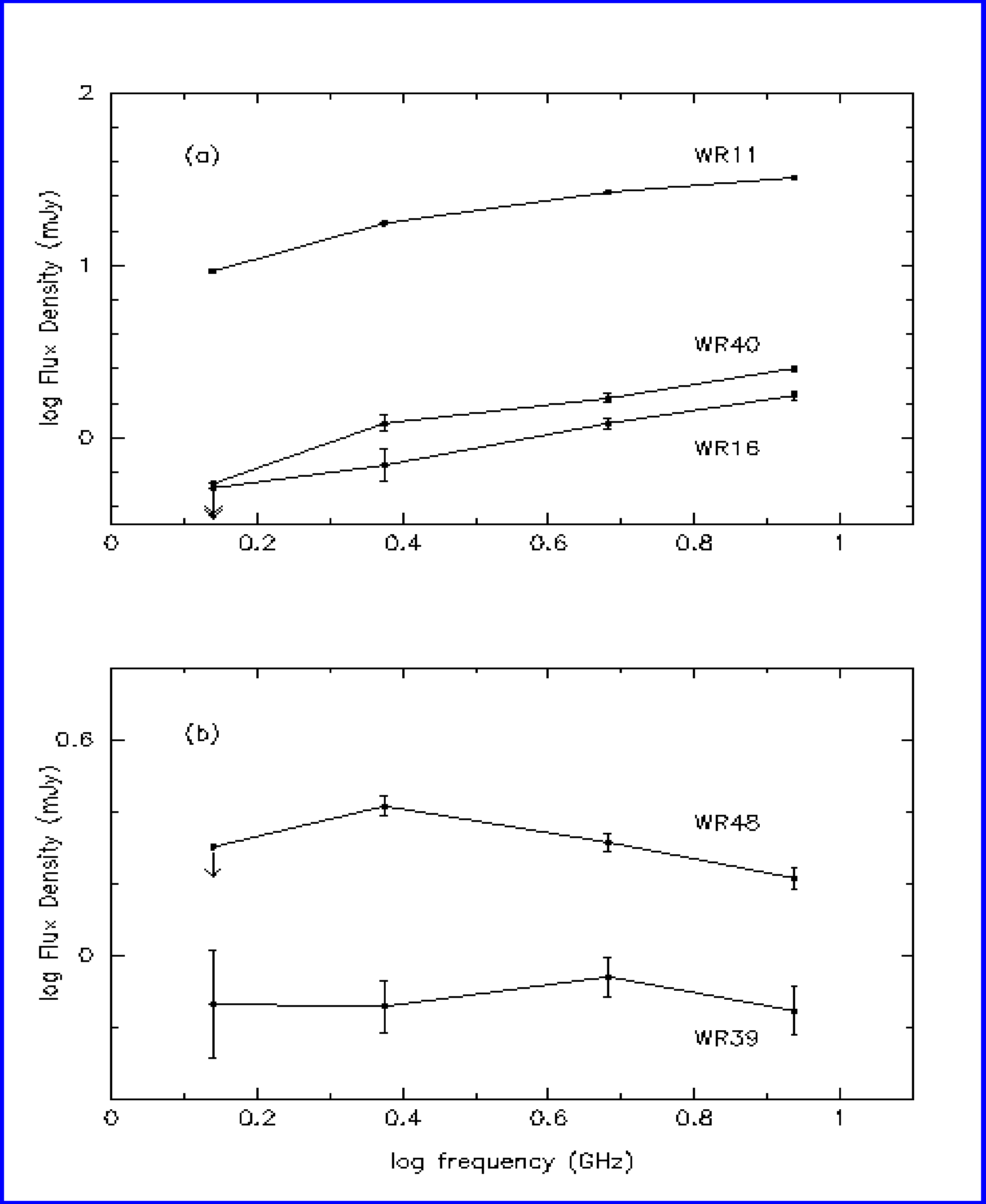
- ♦ reduce the sidelobes from other sources in the field
- ♦ may reduce the level on interference

Detection of stellar winds from WR stars

Band	rms (mJy)	time (mins)
3	0.1 ▸ 0.2	70
6	0.1 ▸ 0.6	70
13	0.1 ▸ 1.2	70
20	0.2 ▸ 1.3	70

WR112 - 13 cm





Radio continuum spectra for WR stars

Confusion

- any other astronomical source that contributes to emission
- may be within the primary beam or in sidelobes
- degrades final images - higher noise in images
- may give spurious “detections”

Confusion..

Number of extragalactic sources per square arcmin:

$N(S_{obs} > S) = 0.032\ S^{-1.3}$ at 6 cm

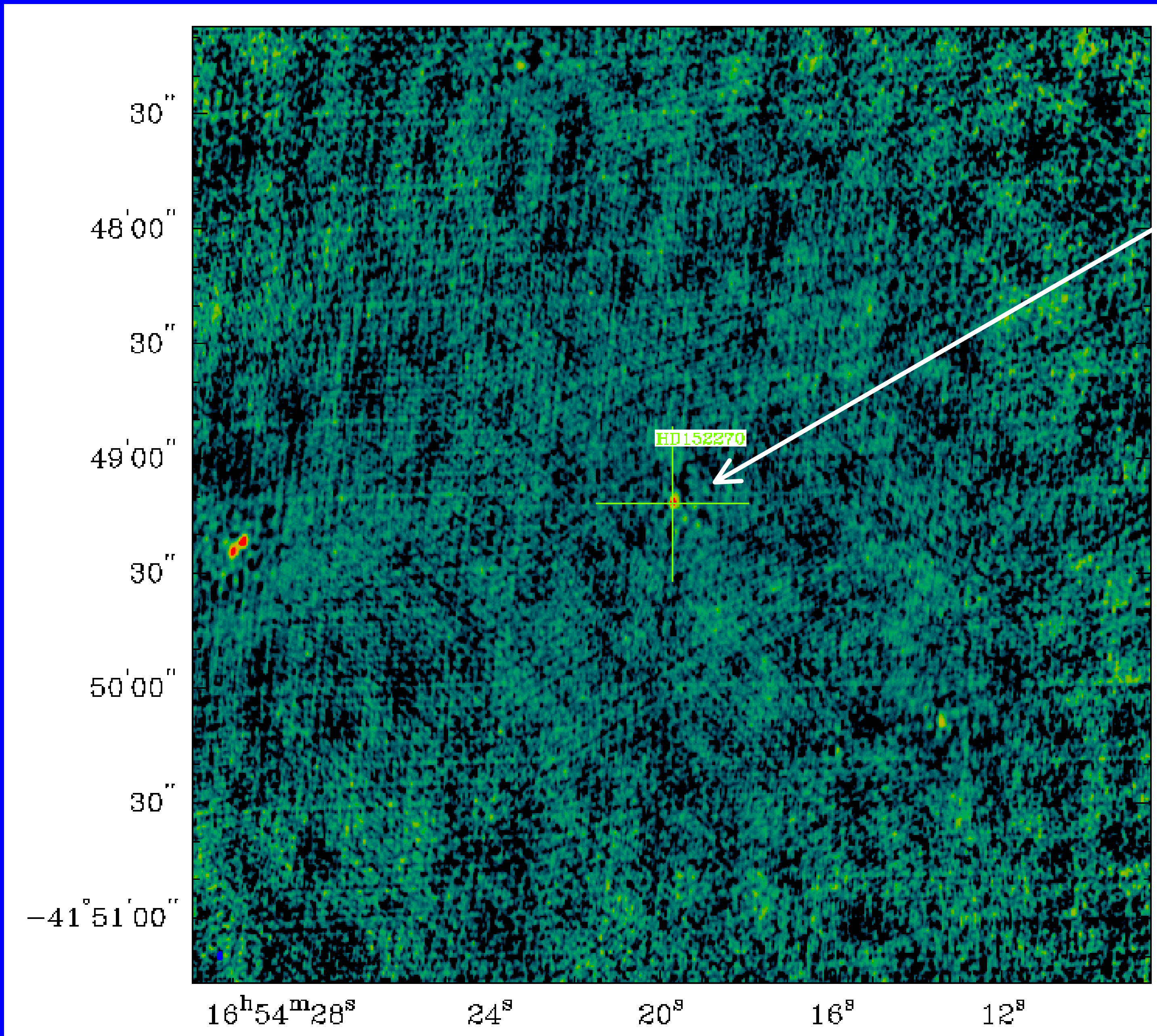
$= 0.10\ S^{-0.9}$ at 20 cm

Examples: At 20 cm, primary beam ~ 1000 arcmin^2

N >20 mJy ~ 7

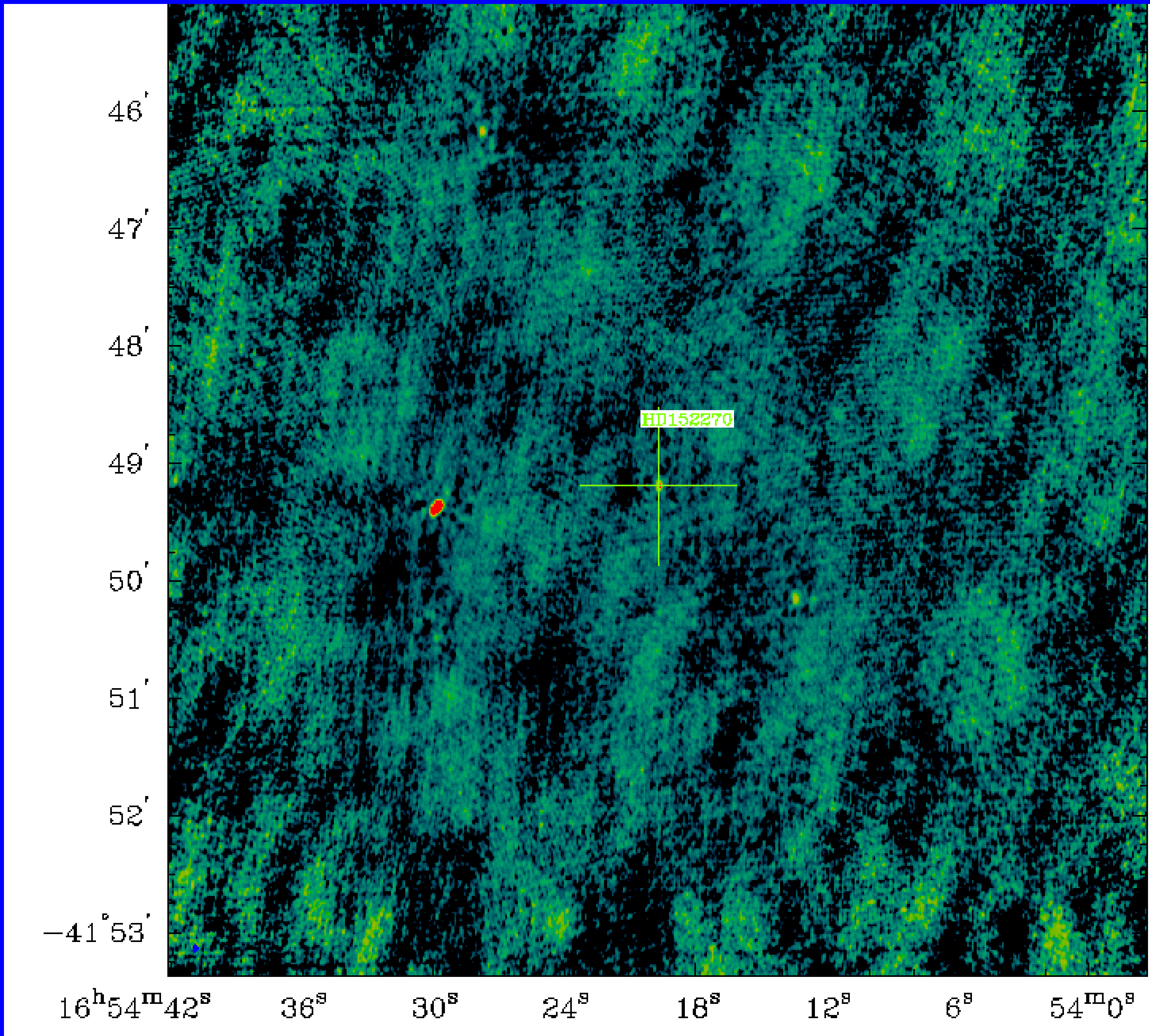
N > 160 mJy ~ 1

At 3 cm expect ~ one source > 0.4 mJy in primary beam

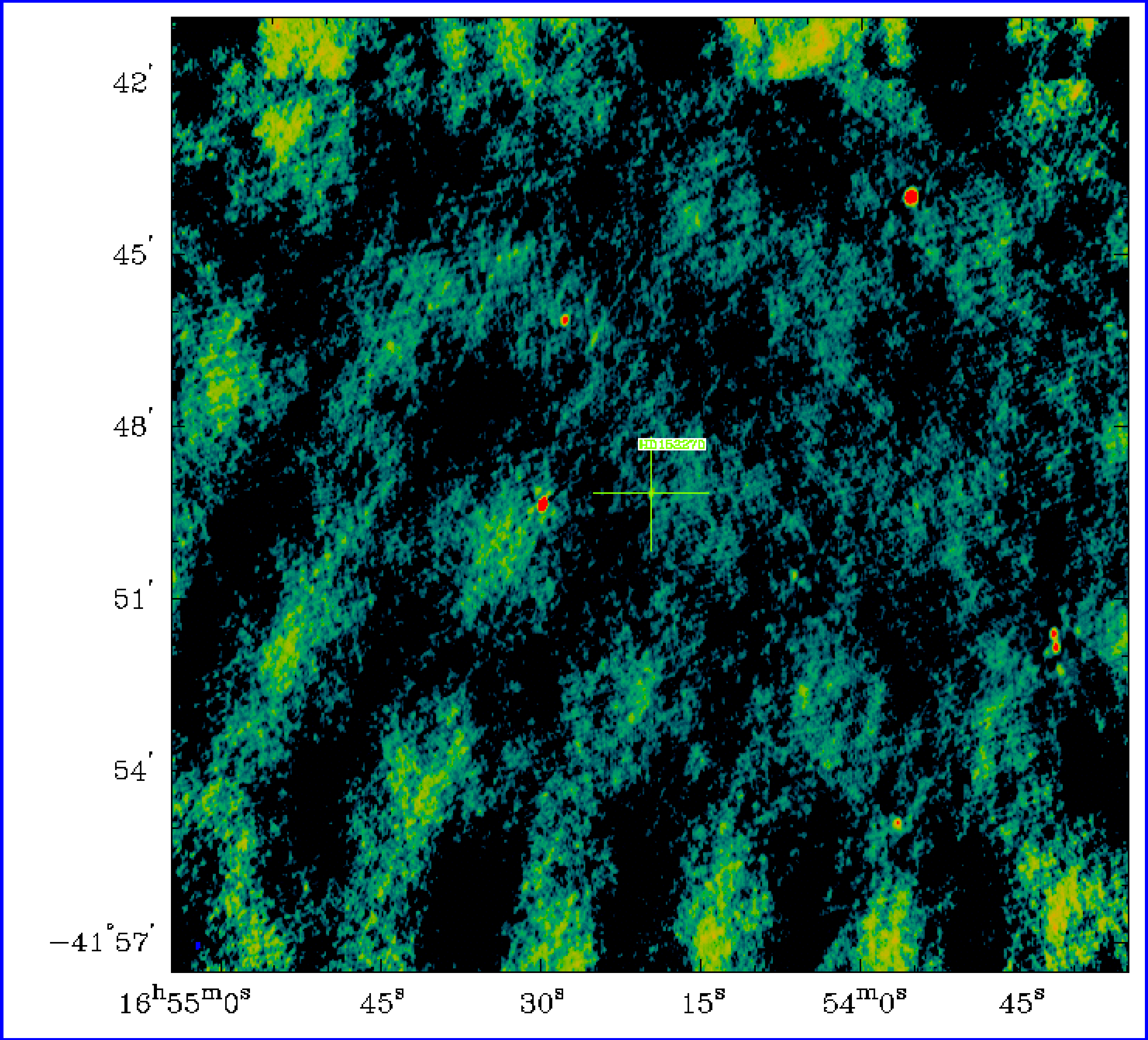


Stellar detection

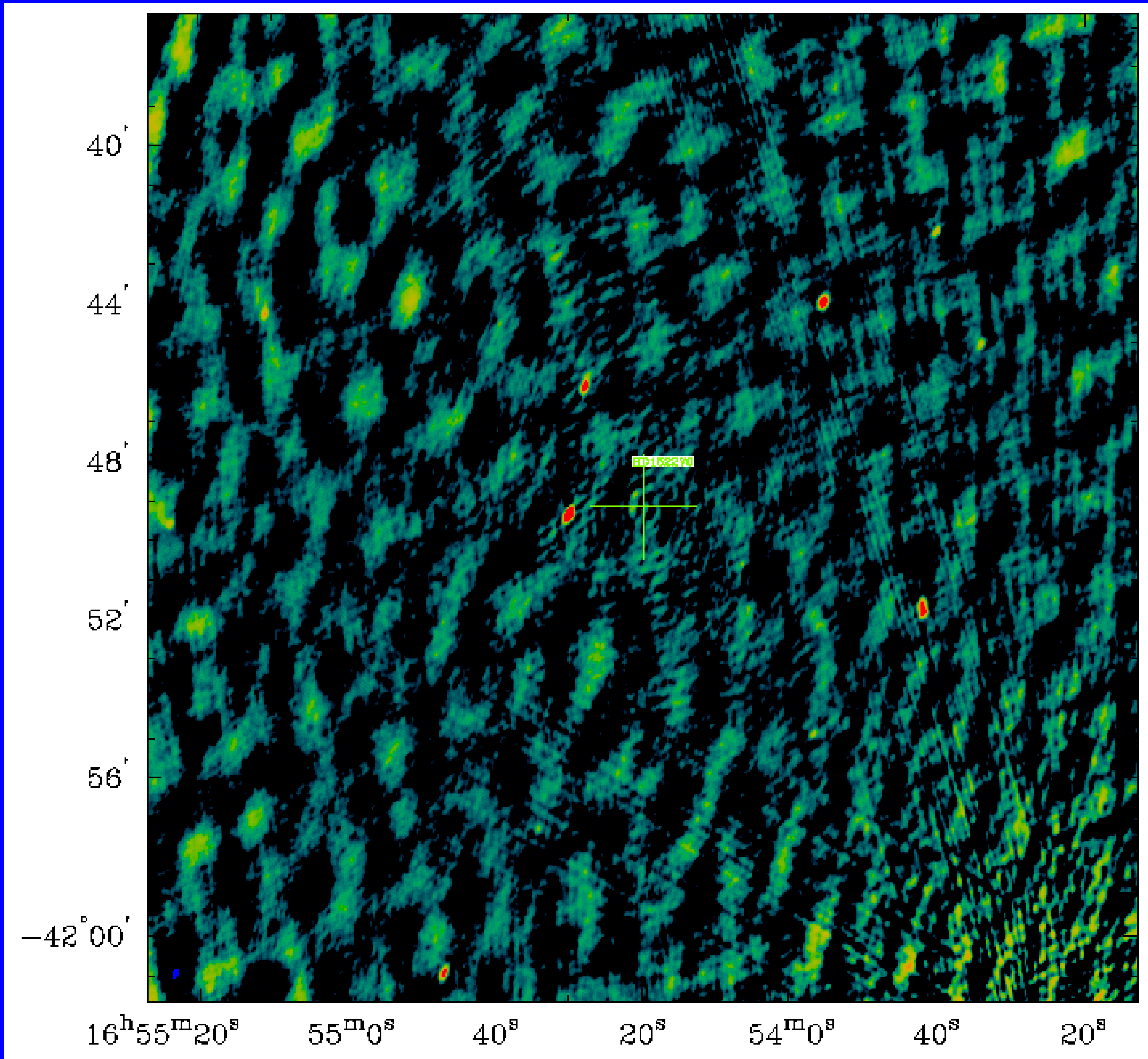
3 cm


46'
47'
48'
49'
50'
51'
52'
−41°53'
16h54m42s
36s
30s
24s
18s
12s
6s
54m0s
HD152270

6 cm



13 cm



20 cm

Some Strategies for Confusion

- Make a low resolution image of a large region

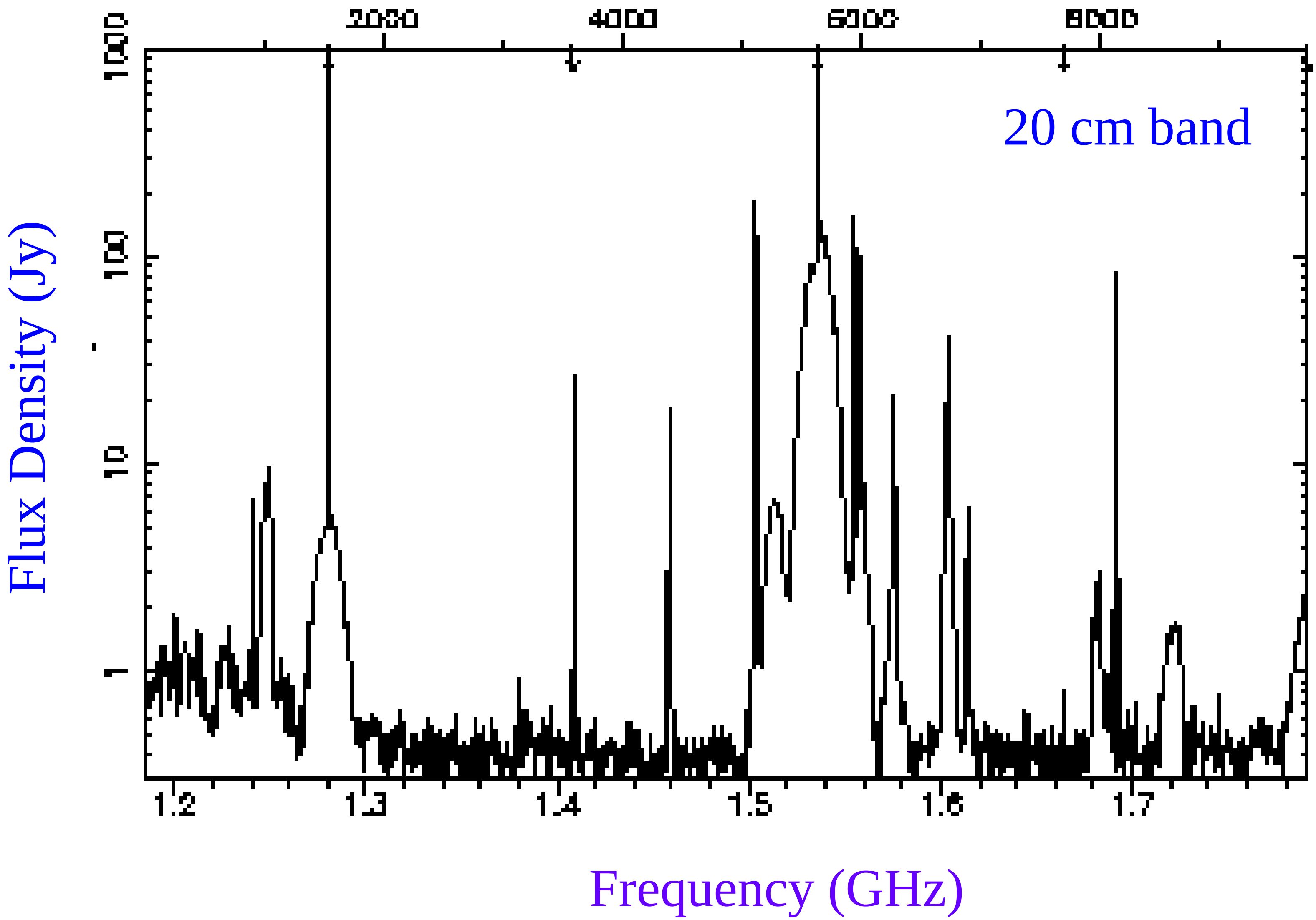
- Identify and CLEAN sources within field-of-view

- Move pointing centre away from strong confusing source
  -- to minimize the primary beam response

- For short cut experiements - use multiple cuts
  -- improves the dirty beam characteristics

- Be careful with marginal detections - are they just sidelobes?

Interference



Interference...

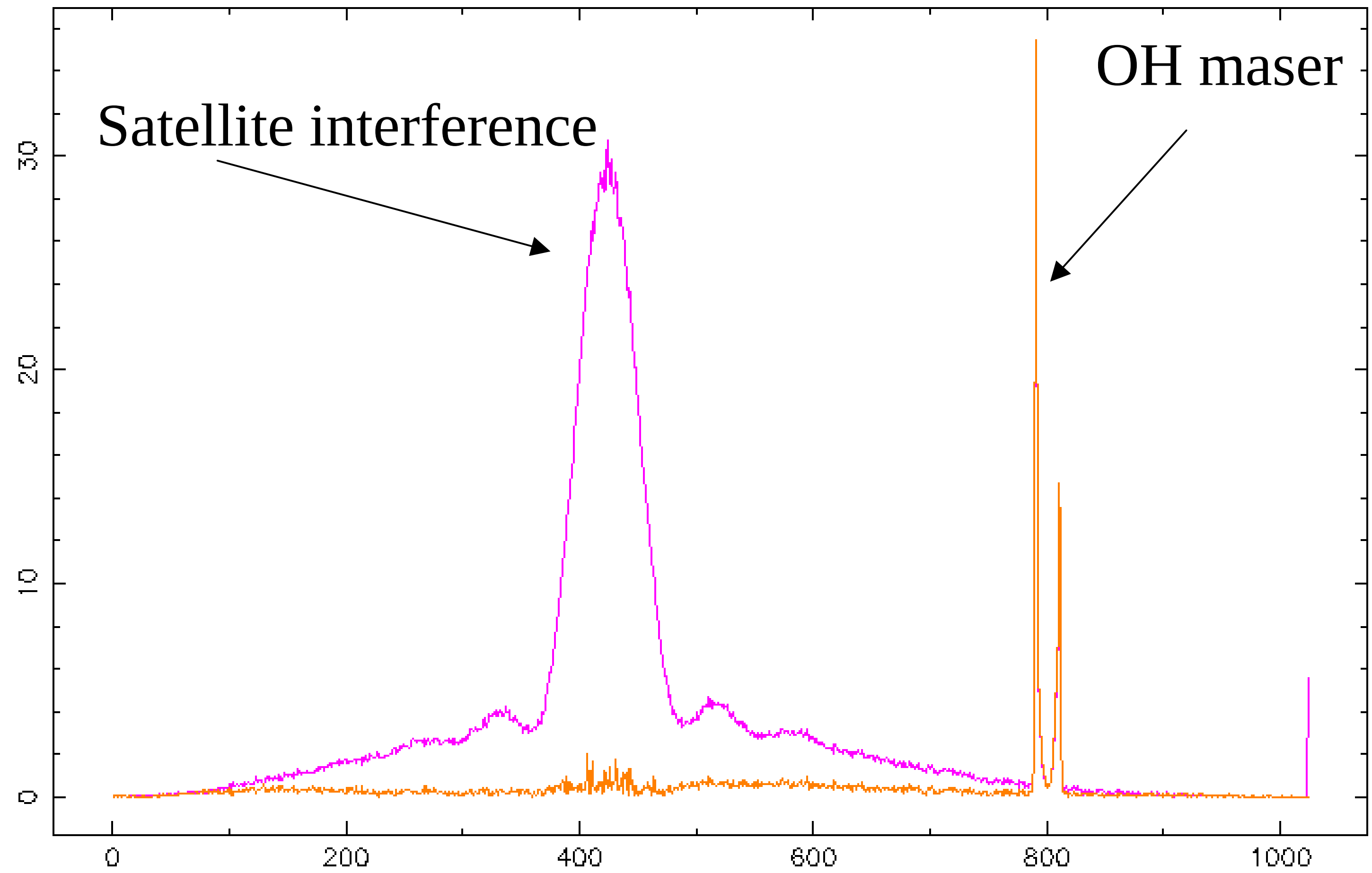
characteristics

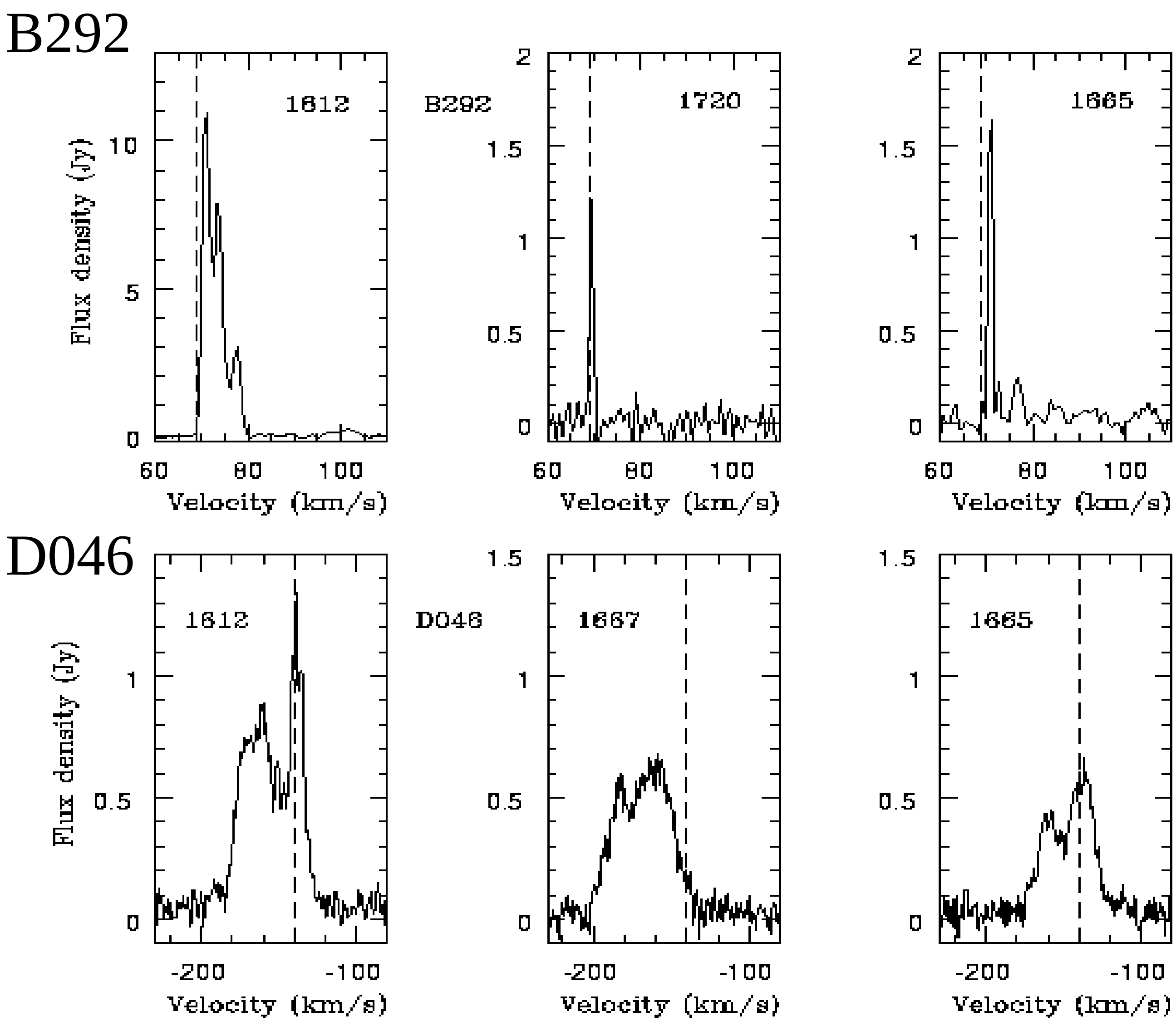
- time variable
- short bursts -- large angular scale map errors
- worst on short baselines

strategies

- avoid the sun (> 40 degrees)
- choose ‘clean’ part of band – see guide and staff
- use long exposures or multiple cuts
- use longer baselines
- edit data

Interference can be removed using pre- and post-correlation techniques





B292
1612
B292
1720
1665
Flux density (Jy)
Velocity (km/s)
60
80
100
0
5
10
0.5
1
1.5
2
D046
1612
D046
1667
1665
Flux density (Jy)
Velocity (km/s)
-200
-100
0
0.5
1
1.5