



WALLABY Source Finding Tests

Data Sets and Algorithms

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WALLABY

- The **Wide-field ASKAP L-band Legacy All-sky Blind Survey**.
 - PIs: **Bärbel Koribalski** & **Lister Staveley-Smith**
- **Main aim:**
 - Catalogue of extragalactic H I sources out to $z \approx 0.2$.
- **Source finding requirements:**
 - 3-dimensional source finding in (α, δ, ν) space.
 - Objects spatially compact, but well resolved in velocity / frequency.
 - 500,000 expected galaxies, hence fully automatic source finding and cataloguing required.
- **TWG 4 – “Source Finding and Cataloguing”:**
 - *D. Barnes, G. Józsa, N. Gupta, T. Henning, T. Jarrett, H. Jones, R. Jurek, V. Kilborn, B. Koribalski, Á. López-Sánchez, T. Murphy, T. Oosterloo, A. Popping, P. Serra, T. Westmeier, M. Whiting, B. Winkel*



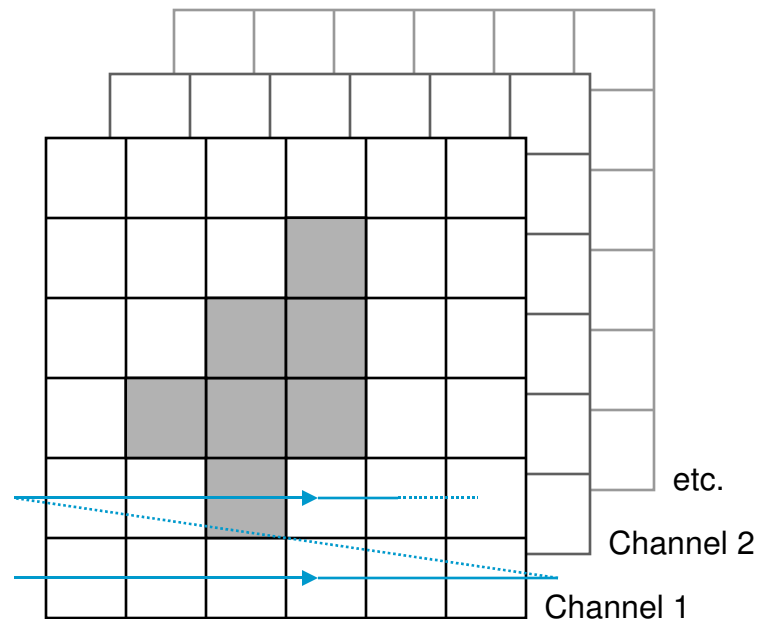
Source Finding Algorithms

Duchamp

- Duchamp developed my **Matthew Whiting** at ATNF.
- Duchamp scans data cube for pixels above a given threshold.
- Detections will be joined into objects under various conditions.
- Several methods of filtering can be applied.
- Duchamp makes no assumptions about source morphology.

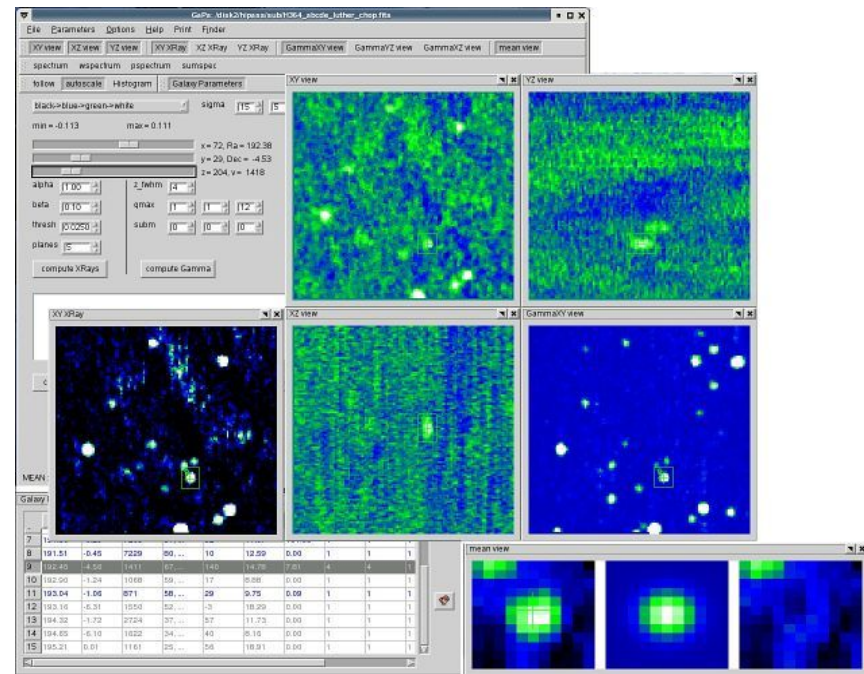
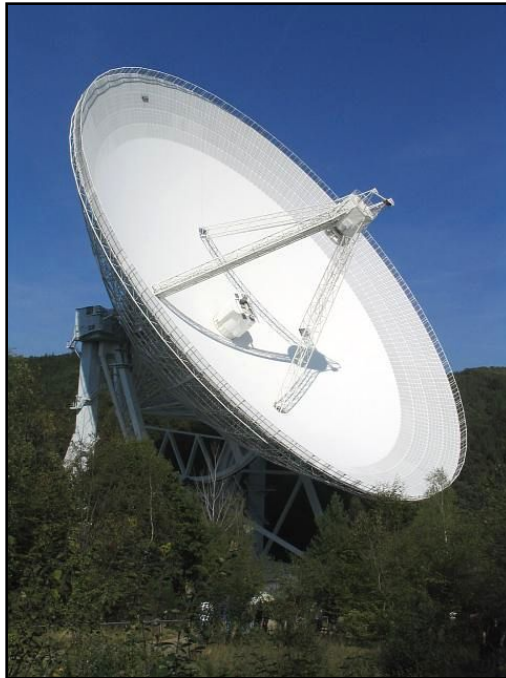


Marcel Duchamp (1887–1968)



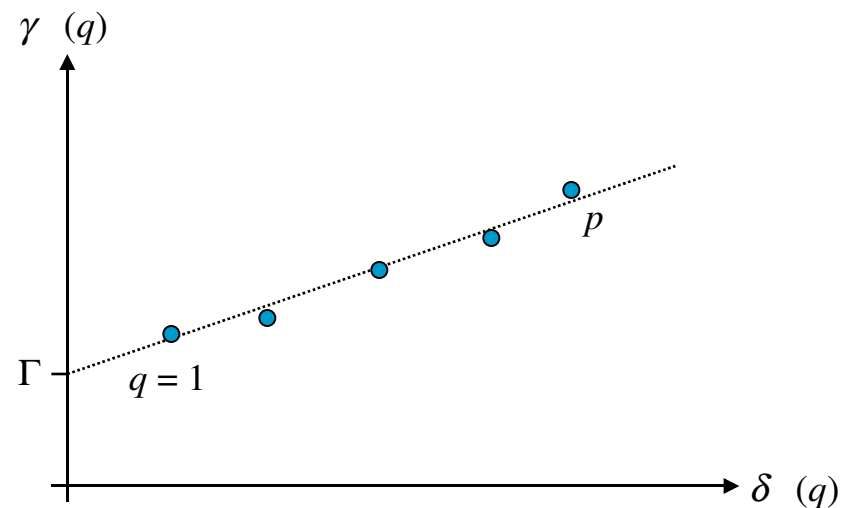
Gamma Test

- Source finder based on Gamma Test developed by Benjamin Winkel in Bonn.
- Used for the Effelsberg all-sky H I Survey.



Gamma Test

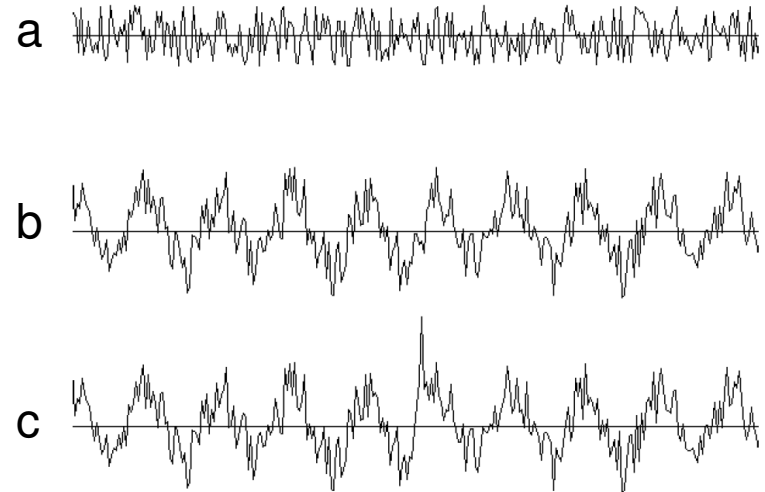
- Assume spectrum with noise + underlying smooth function $f(x)$:
 - $y = f(x) + n$
- Define the following two functions:
 - $\gamma(q) = (1/2M) \sum |y_{N(i,q)} - y_i|^2$
 - $\delta(q) = (1/M) \sum |x_{N(i,q)} - x_i|^2$
- Linear relation between $\gamma(q)$ and $\delta(q)$:
 - $\gamma(q) = A \times \delta(q) + \Gamma$
- Offset Γ equal to variance of spectral baseline noise:
 - $\sigma^2 = \Gamma$
- Gamma Test allows determination of noise!



(For details see Evans & Jones 2002; Boyce 2003)

Gamma Test

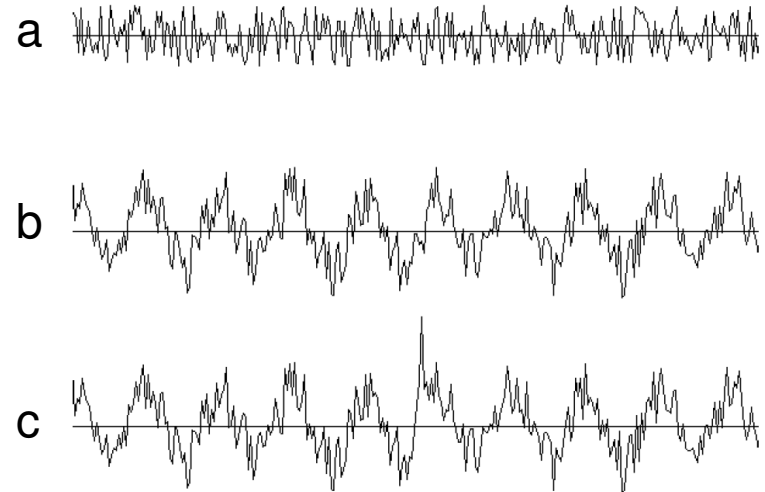
- Gamma Test on artificial noise spectrum with rms of 15 mJy.
- Case a: Gaussian noise
 - $\Gamma^{1/2} = 15.3$ mJy (✓)



Peter J. Boyce (2003), Master Thesis

Gamma Test

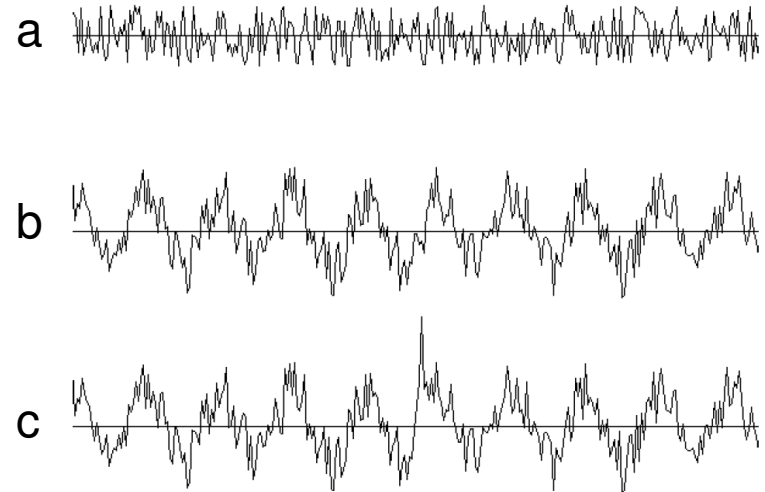
- Gamma Test on artificial noise spectrum with rms of 15 mJy.
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 - $\Gamma^{1/2} = 15.3$ mJy (✓)
- Case b: Gaussian noise + baseline ripple
 - $\Gamma^{1/2} = 15.7$ mJy (✓)



Peter J. Boyce (2003), Master Thesis

Gamma Test

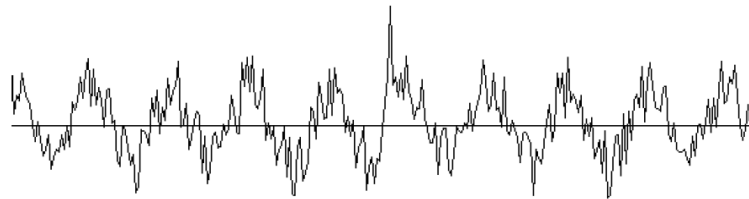
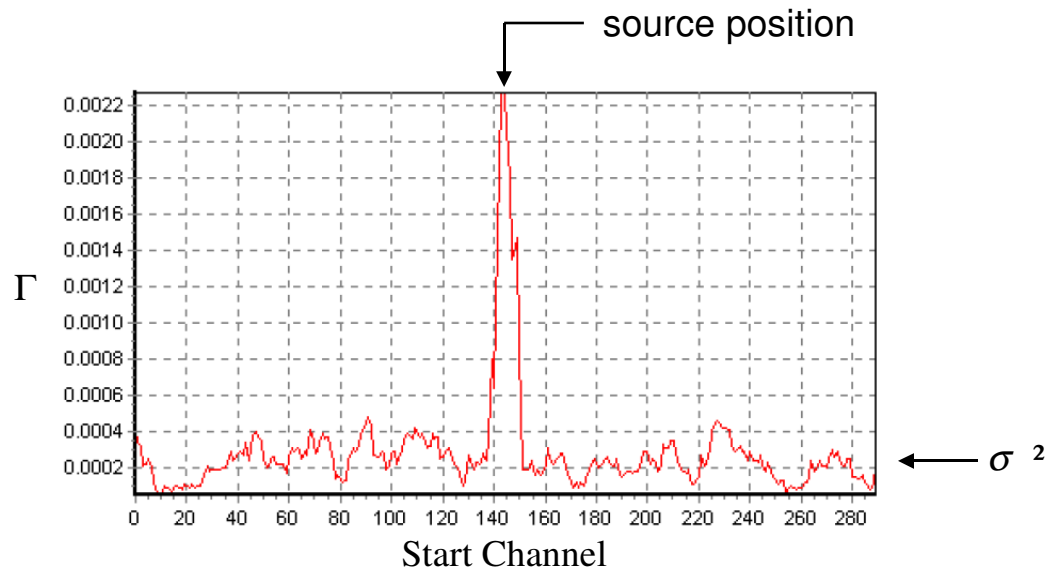
- Gamma Test on artificial noise spectrum with rms of 15 mJy.
- Case a: Gaussian noise
 - $\Gamma^{1/2} = 15.3$ mJy (✓)
- Case b: Gaussian noise + baseline ripple
 - $\Gamma^{1/2} = 15.7$ mJy (✓)
- Case c: Gaussian noise + baseline ripple + narrow emission line
 - $\Gamma^{1/2} = 17.6$ mJy (✗)
- What went wrong?
- Reason: underlying function $f(x)$ not smooth, but narrow emission line.



Peter J. Boyce (2003), Master Thesis

Gamma Test

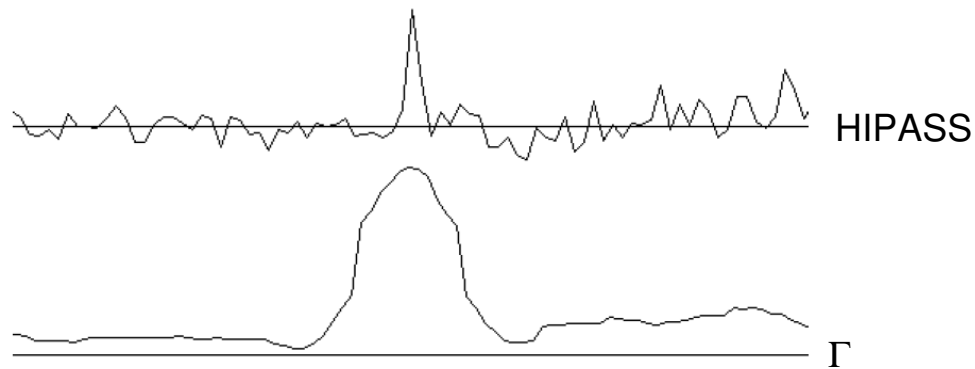
- Let's try a "moving-window" Gamma Test:



Peter J. Boyce (2003), Master Thesis

Gamma Test

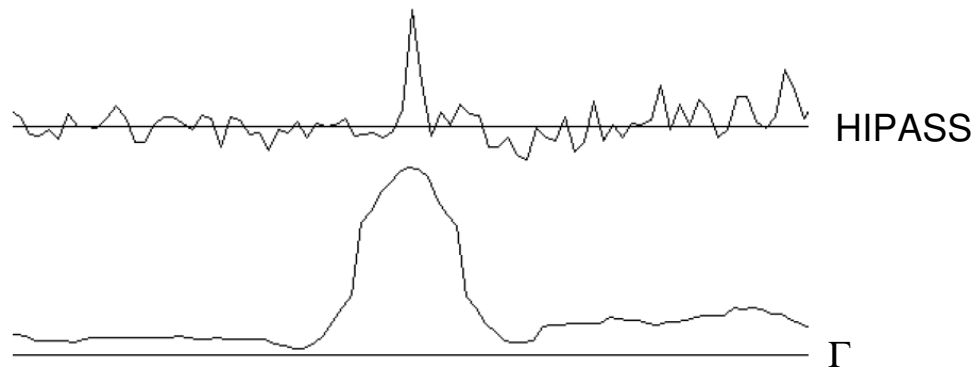
- Gamma Test will detect **compact sources** and certain types of radio frequency interference.
- Example: UGC 05701 from HIPASS



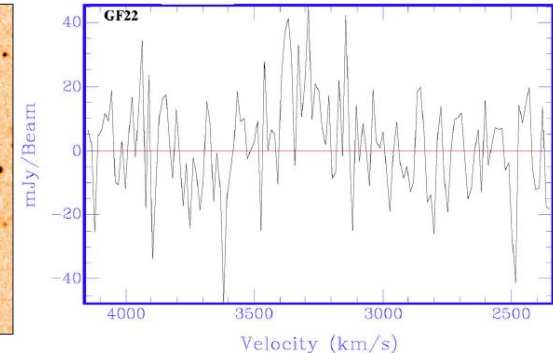
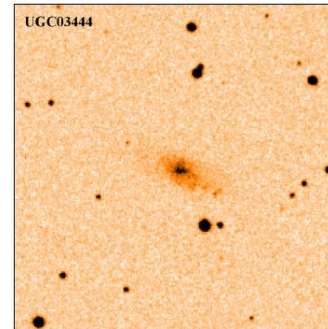
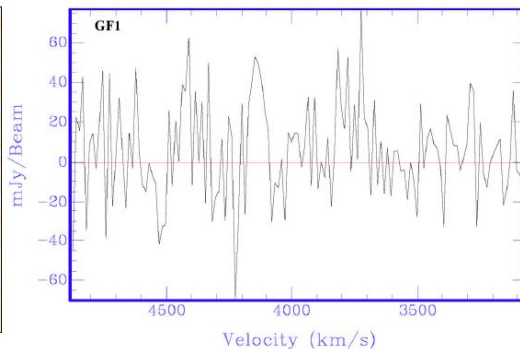
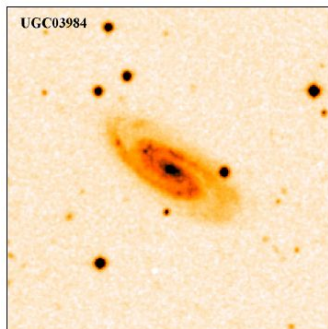
Peter J. Boyce (2003), Master Thesis

Gamma Test

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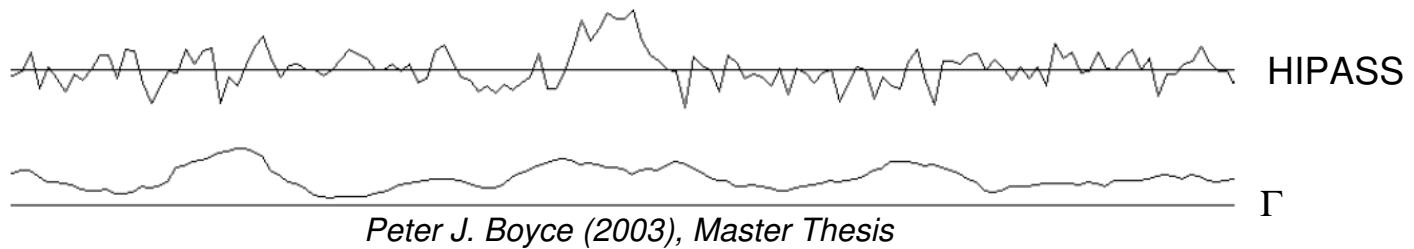


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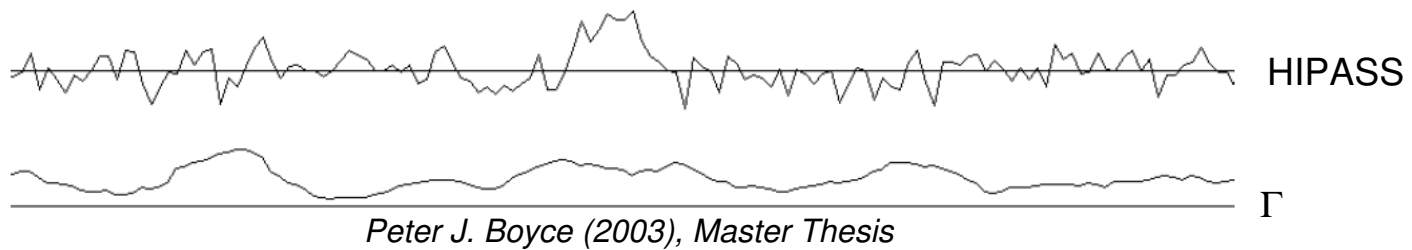
Gamma Test

- What about broad spectral lines?

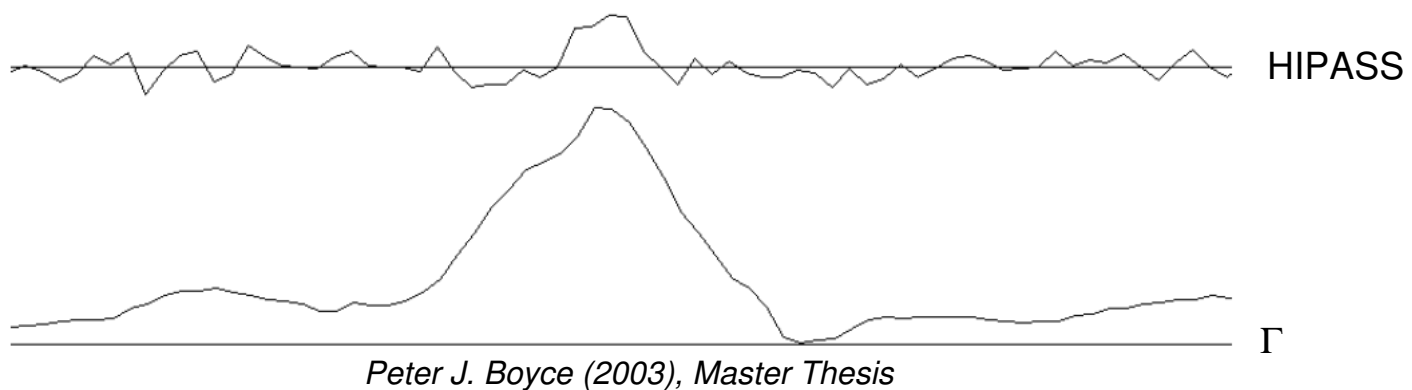


Gamma Test

- What about broad spectral lines?



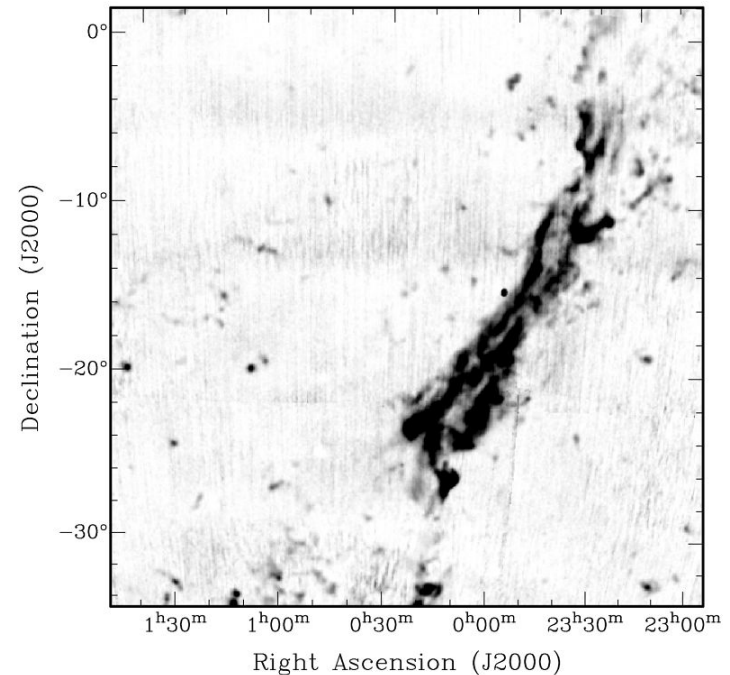
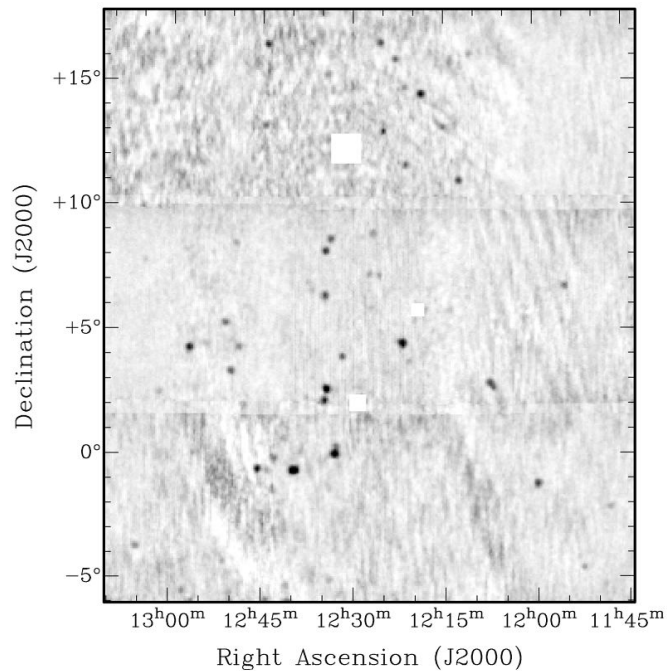
- Solution: Hanning smoothing



Data Sets for Source Finding Tests

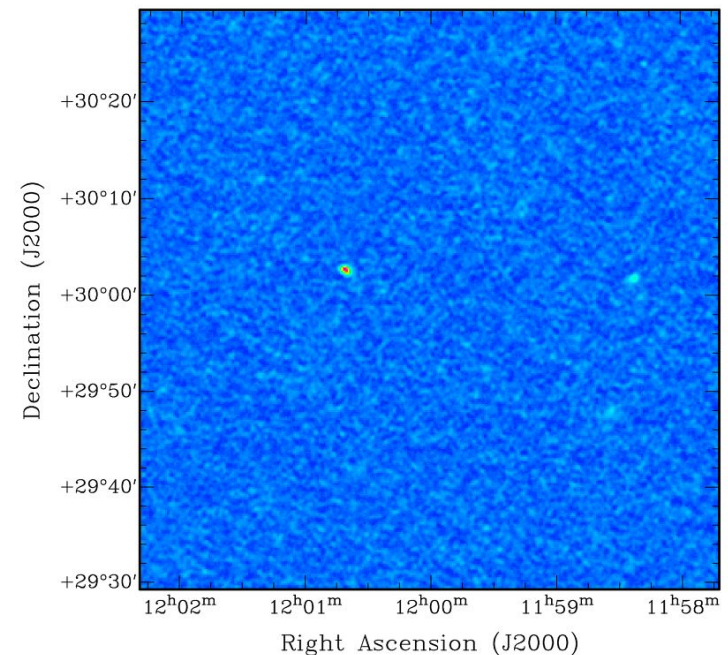
Data Sets: HIPASS

- HIPASS
 - Virgo Cluster
 - Magellanic Stream
- Advantage: real sources (galaxies, high-velocity clouds, etc.).
- Problem: serious artefacts in HIPASS challenging for SFs.



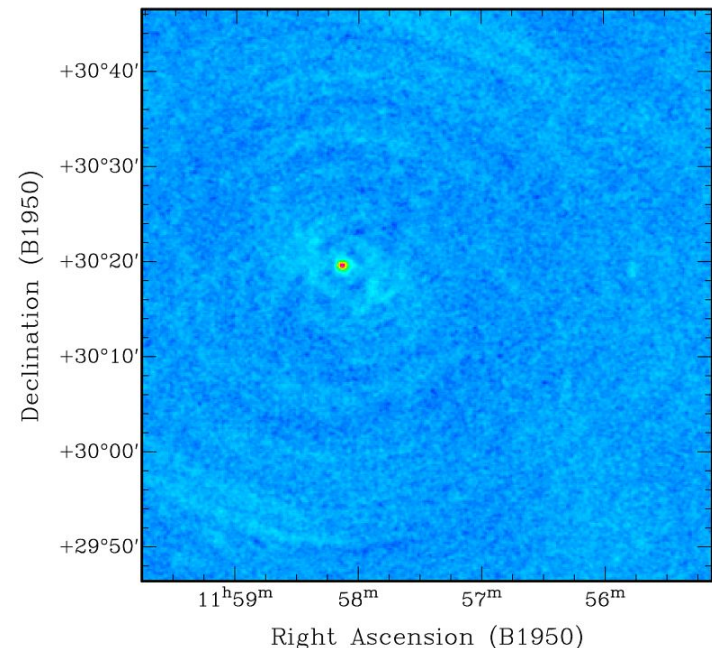
Data Sets: WSRT Model Cube

- Model cube created by **Paolo Serra** at ASTRON.
- 100 WHISP galaxies (van der Hulst et al. 2001), artificially redshifted and copied into WSRT noise cube.
- Parameters:
 - Field of view: 1 deg²
 - Redshift range: 0.02...0.04
 - Spectral channels: 1464
 - Channel width: 18.3 kHz
 - Velocity resolution: 4 km s⁻¹
 - Beam width: 30 arcsec
 - Pixel size: 10 arcsec
 - rms noise: 1.6 mJy
- Advantages: real galaxies and real interferometer noise with telescope errors and RFI.

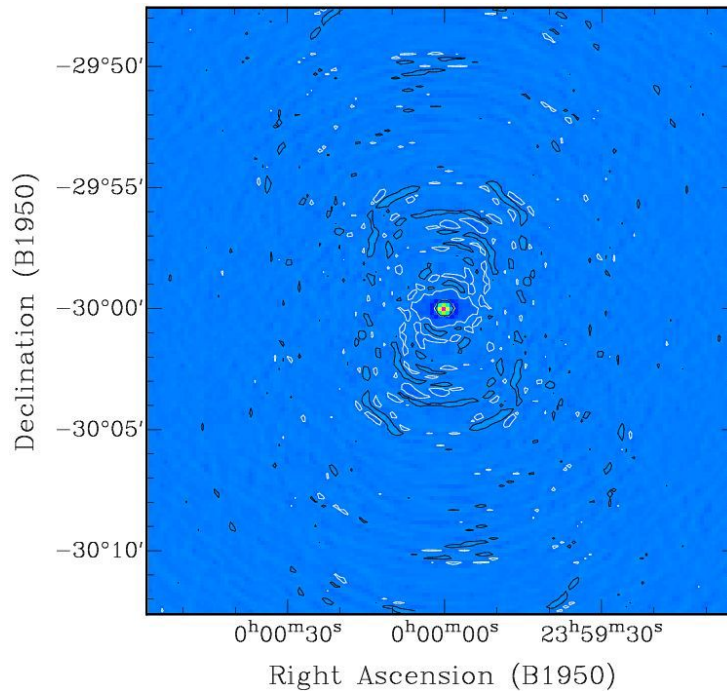


Data Sets: ASKAP Model Cube

- Same 100 WHISP galaxies as in WSRT model cube.
- ASKAP noise and beam model generated with Miriad (uvgen).
- Parameters:
 - ASKAP core configuration of 30 antennas
 - 8 h integration time (hour angles of ± 4 h) in 1-minute intervals
 - $1^\circ \times 1^\circ$ field of view with 10-arc-sec pixels
 - Uniform noise across the field, scaled to about 1.6 mJy
- Even more realistic: real galaxies, ASKAP noise and sidelobes, but no telescope errors and RFI.

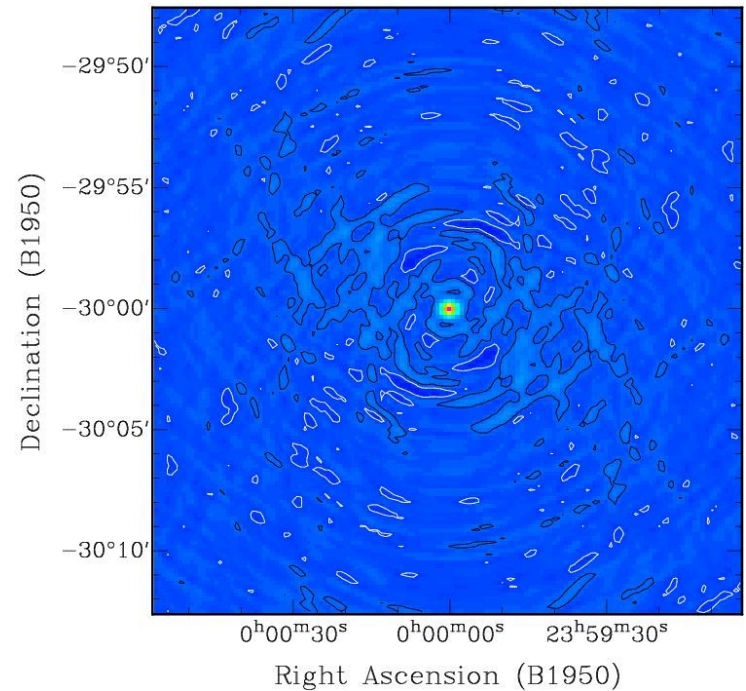


ASKAP Beam and Sidelobes at $\delta = -30^\circ$



Uniform weighting

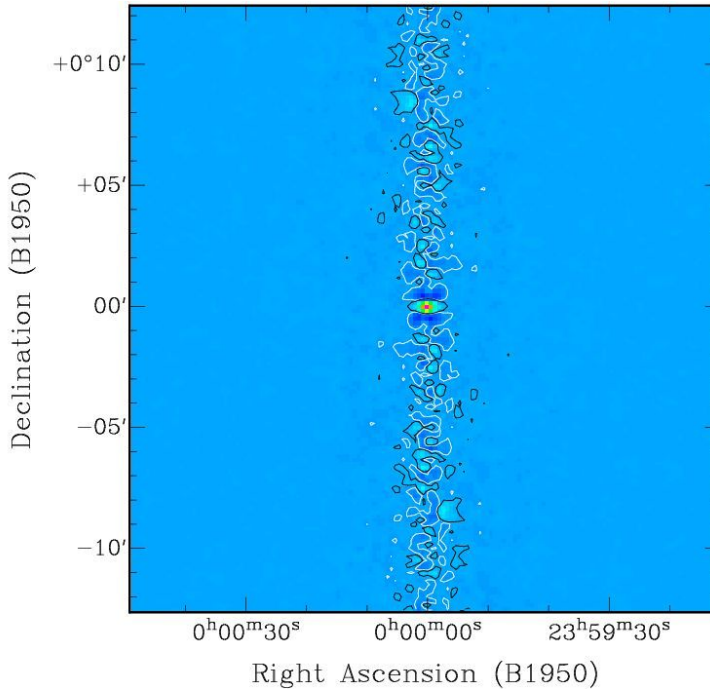
FWHM: 18.9 arcsec
Sidelobes: $-5.5\% \dots +3.1\%$



Natural weighting

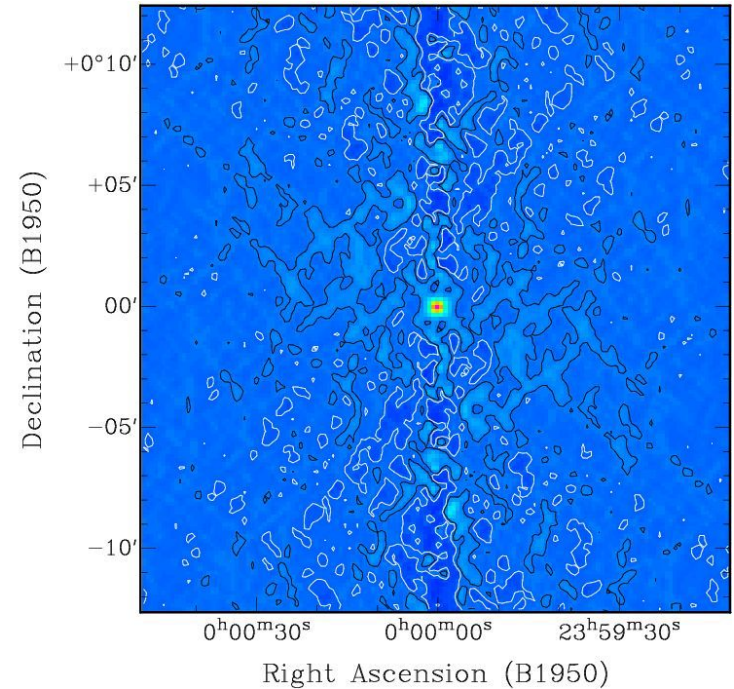
FWHM: 27.5 arcsec
Sidelobes: $-2.4\% \dots +4.9\%$

ASKAP Beam and Sidelobes at $\delta = 0^\circ$



Uniform weighting

FWHM: 21.5 arcsec
Sidelobes: $-9.8\% \dots +15.4\%$

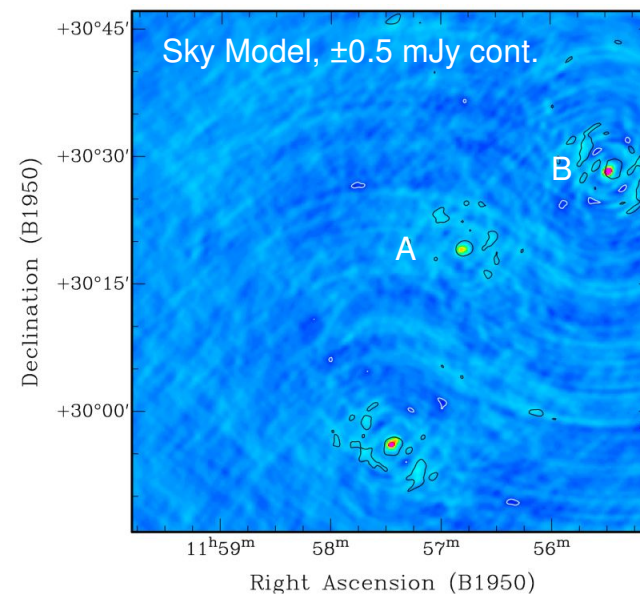
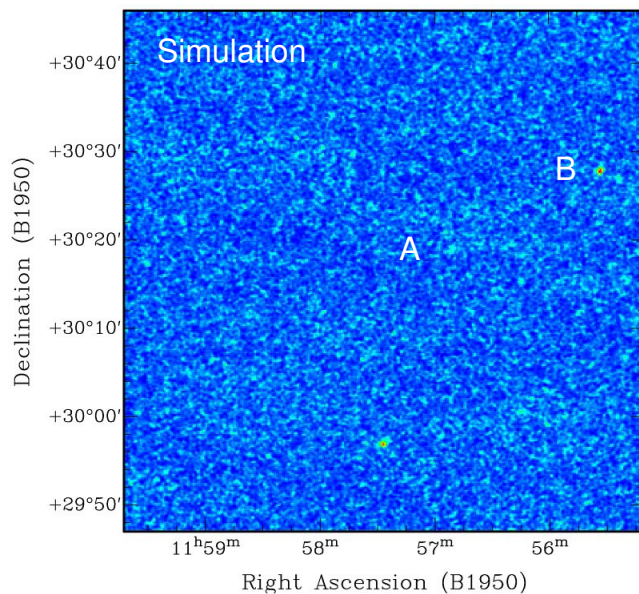


Natural weighting

FWHM: 30.0 arcsec
Sidelobes: $-4.2\% \dots +19.8\%$

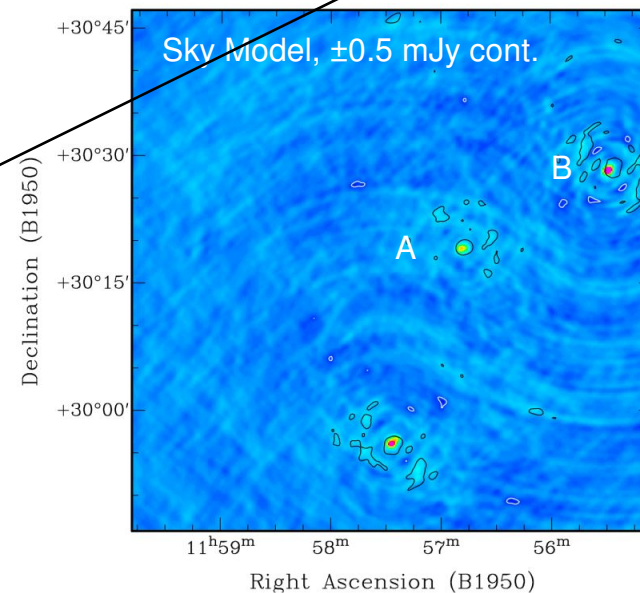
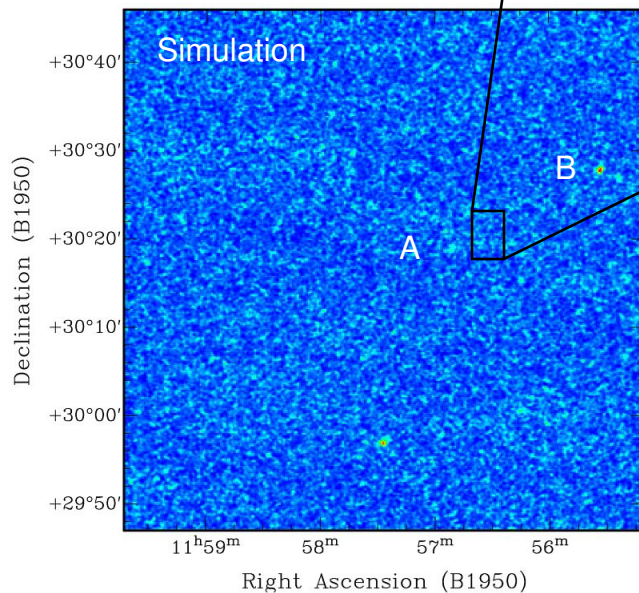
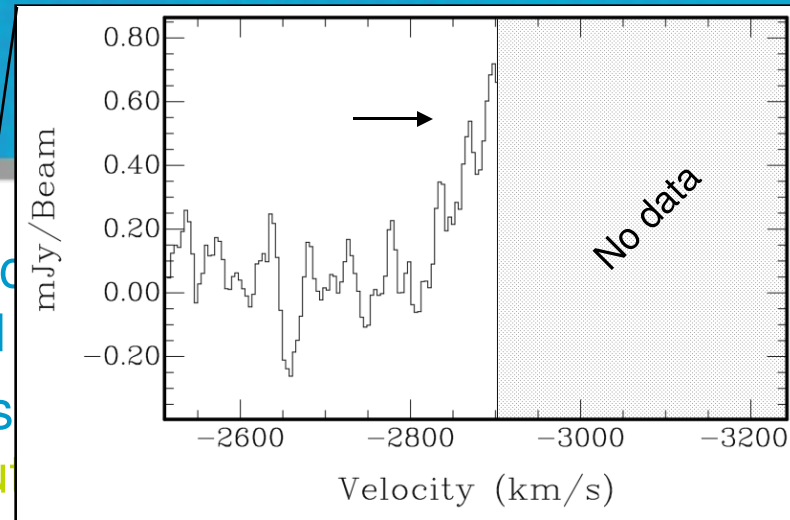
Deconvolution and Stacking

- Sources of **100 mJy** will cause noticeable **sidelobes** in WALLABY data cubes (1.6 mJy rms).
- There will be dozens of sources with $S > 100$ mJy in each field of 30 deg^2 , so **deconvolution** generally required.
- Low sidelobe levels could be a problem for certain **stacking** experiments which will pick up sidelobes as well.



Deconvolution and

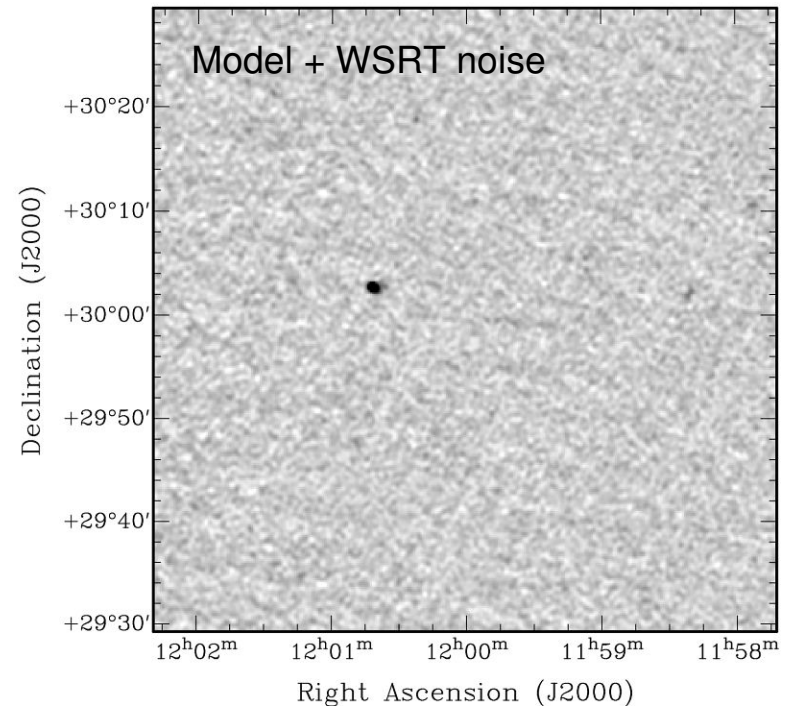
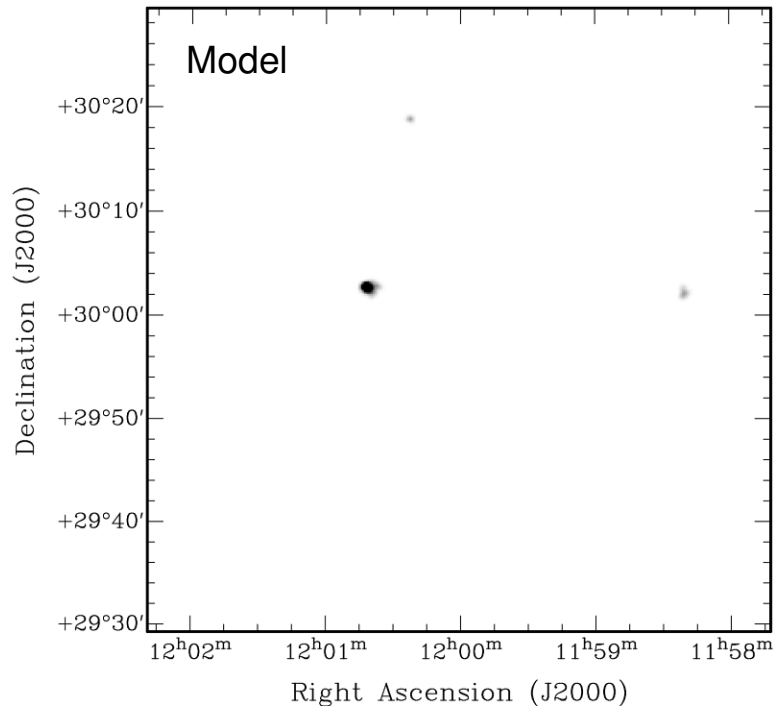
- Sources of 100 mJy will be detected in WALLABY data cubes (1.4 GHz)
- There will be dozens of sources per field of 30 deg², so deconvolution is essential
- Low sidelobe levels could be a problem for certain stacking experiments which will pick up sidelobes as well.



First Results

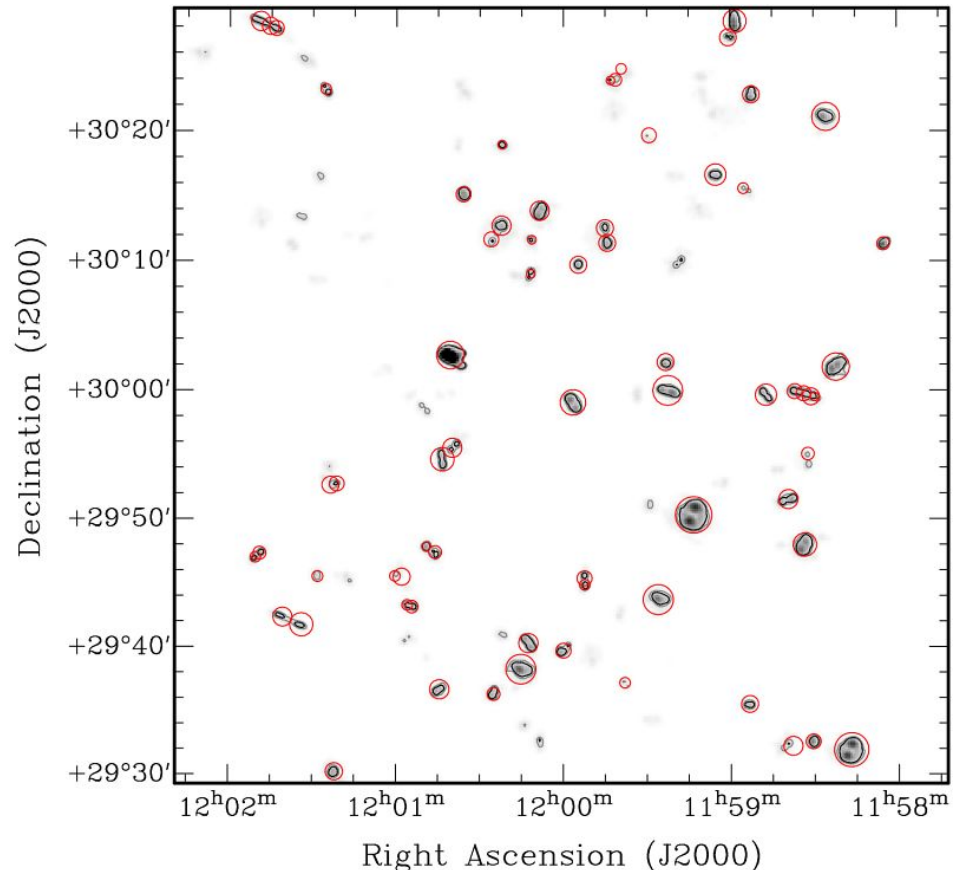
Duchamp vs. WSRT Model Cube

- Running Duchamp on WSRT-based model cube.
- Model contains about 100 artificially redshifted WHISP galaxies.



Duchamp vs. WSRT Model Cube

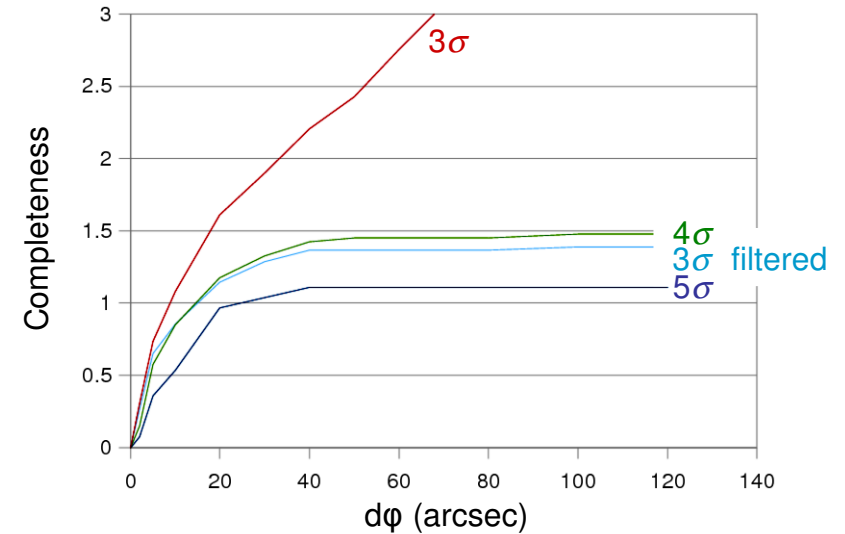
- 4σ and 5σ cutoff levels fast and efficient.
- 3σ cutoff detected thousands of noise peaks.
 - 4061 detections!
- Extensive filtering of 3σ results.
 - Removal of false detections.
 - But: enormous time penalty (many hours on standard PC).
- Yet, 3σ results very promising.



Duchamp vs. WSRT Model Cube

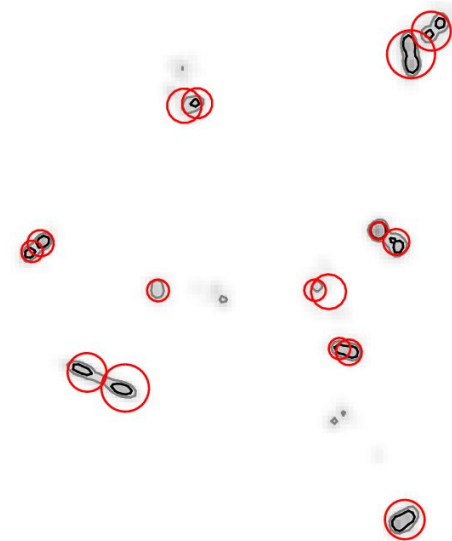
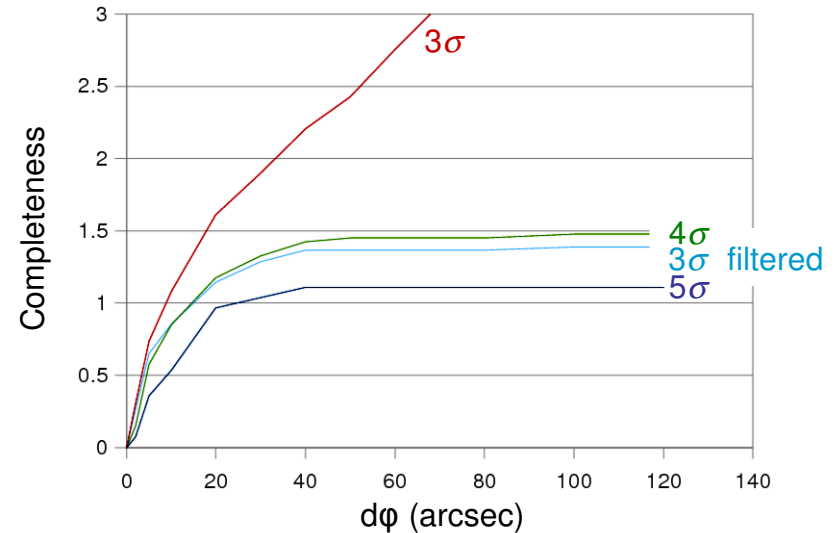
- **Completeness:**

- 3σ : 4061 / 49 sources
- 4σ : 59 / 40 sources
- 5σ : 31 / 28 sources
- 3σ (filt.): 68 / 49 sources



Duchamp vs. WSRT Model Cube

- **Completeness:**
 - 3σ : 4061 / 49 sources
 - 4σ : 59 / 40 sources
 - 5σ : 31 / 28 sources
 - 3σ (filt.): 68 / 49 sources
- **Why more than 100% completeness?**
 - Double-peak profiles of faint edge-on galaxies detected as two (or more) separate sources.
- **For the same reason, completeness below 100% for smaller search radii (< 40 arcsec).**



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Thank you

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